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Semiannual Report No. 3

ENVIRONMENTAL DATA BASE FOR REGIONAL STUDIES IN THE HUMID TROPICS

USATECOM Project No. 9-4-0013-01

October 1967

US Army Tropic Test Center
Fort Clayton, Canal Zone

Sponsored by

Advanced Research Projects Agency, ARPA Order No. 740
and
Army Research Office, OCRD, Project No. 2M025001A724 01

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Report Period: 1 September 1966 through 28 February 1967

This research was supported by the Advanced Research Projects Agency of the Department of Defense and by the Army Research Office, OCRD, Department of Army.

Conducted by

U.S. Army Test and Evaluation Command
U.S. Army Tropic Test Center, Fort Clayton, Canal Zone
with assistance of Weather Engineers of Panama Corp.
Contract DA96-519-SCAR-2374

October 1967

FOREWORD

This summary report, the third of a series to be issued semiannually, covers the progress and status of the Environmental Data Base for Regional Studies in the Humid Tropics. The project is sponsored by the Office, Secretary of Defense, Advanced Research Projects Agency (ARPA), Directorate of Remote Area Conflict, and by the Department of Army, Office of Chief of Research and Development, Army Research Office (ARO).

The study reported herein is being conducted under the guidance and with the direct participation of the Research Division of the US Army Tropic Test Center. The Commanding Officer during the report period was Colonel Pedro R. FlorCruz. The Commanding Officer, at time of publication, is Colonel John Zakel, Jr. The research program is carried out under the supervision of Dr. Guy N. Parmenter, Chief of the Division. Staff members of the Division have been responsible for the preparation of the individual study papers comprising the body of this report, as noted herein. Compilation and arrangement of the report has been done by Mr. Edward E. Garrett, Physical Environmental Scientist of the Division.

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SUMMARY

This report, the third in a series of semiannual progress reports of the Environmental Data Base Project, presents a resume of Project objectives and methods and descriptions of the operational sites.

The Climate section (Part IV) shows the data collected and instrumentation used with a description of automatic instrumentation planned. Analyses of daily temperature variations and a discussion of soil-surface temperature determination are presented.

The Soils and Hydrology section (Part V) presents analyses of soil-moisture profiles and soil-strength profiles and their interrelationships. Detailed information on soil profiles and physical characteristics is presented in an appendix.

The Vegetation section (Part VI) presents analyses of forest litter accumulation. Information on seedling characteristics and seed germination, and a revised vegetation inventory and plot for the Albrook Forest site are given in appendices.

The section dealing with Microbiology and Chemistry of the Atmosphere contains papers on: (a) airborne and surface deposited microorganisms; (b) observations of microbial populations of the forest soil; and (c) a discussion of atmospheric particulate matter.

ENVIRONMENTAL DATA BASE FOR REGIONAL STUDIES IN THE HUMID TROPICS

PART I. INTRODUCTION

Background

This report, covering the period 1 September 1966 through 28 February 1967, is the third in a series of semiannual reports on the progress of the Environmental Data Base for Regional Studies in the Humid Tropics (USATECOM Project No. 9-4-0013-01). It presents a review of project activities during the reporting period along with selected technical data and analyses. Additional technical information will be found in the periodic Data Summaries to be issued under project auspices.

The project is sponsored jointly by the Advanced Research Projects Agency, Office of the Secretary of Defense, and by the Army Research Office, Office of the Chief of Research and Development, Hqs., Dept. of the Army. Work is carried out by the US Army Tropic Test Center, US Army Test and Evaluation Command, Army Materiel Command, with contracted support of Weather Engineers of Panama, Corp. Additional scientific support was received during the reporting period through co-operative arrangements with the National Center for Atmospheric Research, and with several individual scientists.

The project is an interdisciplinary investigation of the humid tropical environments of the Canal Zone and the Rio Hato military training reservation. These environments include a high rainfall region on the Caribbean slope of the Isthmus where tropical evergreen broadleaf forest prevail, a less wet region on the Pacific slope where tropical semideciduous forests predominate, and the still drier Rio Hato region where a typical savanna association is found. The latter two areas are characterized by a pronounced dry season (though the Caribbean, or Atlantic, site has a relatively dry season, it is not so well marked). These areas are analogous to environments in regions of tropical monsoon and tropical savanna climates (Koeppen Am and Aw) in southeast Asia and other parts of the tropics.

Objectives

The overall objective of the Data Base project is to provide increased knowledge concerning the militarily significant environmental factors of humid tropical environments. The project is designed to provide a bank of information and analyses derived from observations of selected physical and biological conditions at representative sites in the three natural environments mentioned above. A specific objective of the US Army Tropic Test Center is to obtain detailed information concerning the environments in which its tests are conducted, which information will be of direct value in the planning and accomplishment of tests as well as in the development of tropical test techniques and methods. The project will establish, at the sites chosen as representative of the three specified environmental

regimes, the spatial and temporal variations of a number of natural conditions that affect the durability and operability of materiel as well as such factors as movement, communication, visibility, and the physical performance of troops.

Description of Project

Tasks

The basic program for the Data Base project provides for investigations in the following fields: (1) Climate, specifically its microaspects, or the meteorological phenomena manifested between the ground surface and a height of approximately 50 meters; (2) Soils and hydrology, with emphasis on factors related to soil trafficability and ground water; (3) Vegetation, with emphasis currently being placed on taxonomy, foliage canopy, and the ground accumulation of forest debris (litter); (4) Microbiology, with emphasis on numbers and kinds of bacteria and fungi and their transportation and deposition; (5) Macrofauna, currently limited to selected arthropods; and (6) Atmospheric chemistry, i.e., chemical and physical contaminants of the air.

Detailed study plans providing guidance for various aspects of each project task have been prepared in the form of Project Memoranda. These memoranda are periodically reviewed and revised to accord with current practice and to reflect experience gained in operation of the project.

Observational Approach

In order to obtain as much information as possible on the interrelationships between various environmental factors, investigations are carried out simultaneously at selected sites. Manpower limitations and the cost of instrumentation have dictated that the full range of observations be limited to a few main observational sites. Two are in operation; three others are planned. "Main" sites are established where a broad range of environmental elements will be observed over a relatively long period of time. Additional "satellite" sites will be, and have been, established in the same general area, at places with different physical and biological conditions where restricted data are observed.

The project plan calls for establishing two main observational sites in each of the two major environmental types found in the Canal Zone. A fifth site is planned for the Rio Hato military reservation where the third principal local variation of the tropical environment is found. The two observational sites in the semideciduous forest environment on the Pacific side of the Canal Zone are now in operation. One is within the forest the other in a large clearing nearby. A similar pair of sites is planned r the tropical evergreen broadleaf forest environment on the wetter Caribbean side of the Canal Zone. The paired sites are necessary in order to fully characterize conditions in each of the two environments. Both cleared land and forest are extensive throughout the humid tropics and military

operations are not confined to one or the other, yet each imposes significantly different environmental conditions affecting movement, visibility, deterioration of materiel, etc.

Some of the observations are made by Tropic Test Center personnel; however, most of the routine observations are made under contract by the Weather Engineers of Panama Corp., following guidance provided in the Project Memoranda. Project scientists on the Tropic Test Center staff monitor all work and provide additional guidance as necessary. The frequency of observation varies with the nature of the parameter, ranging from the continuous reading of some meteorological instruments to the one-time observation of some soil factors. The high frequency of many observations requires manning of the main sites on a 24-hour basis.

PART II. OBSERVATION SITES

Site Locations

General

The selection of sites within the Canal Zone which are representative of the generalization, "Humid Tropics", is complicated by the scarcity of land that is not significantly subjected to influences stemming from cultural or industrial activities and at the same time is available for continued use (for one to two years) by military agencies for research purposes. The sites must be readily accessible to the personnel required for performing the necessary observations and maintenance. Physical security to preclude molestation must be provided for the costly instrumentation. The requirement for electric power necessitates close access by road, or nearness to power lines. Furthermore the sites should, as nearly as practicable, represent the extreme developments of the range of environmental variation that occur within the area. The variational range within the isthmian region is, indeed, large for its comparatively small size, but is not by any means inclusive of all variations for the world's humid tropics. All of these considerations limit site selection and may force some compromise to be made in their choice.

Established Sites

Two main observational sites have been established to date. These are located on the Pacific side of the Canal Zone, which is characterized by moderate precipitation (an average annual rainfall of approximately 70 inches) with a pronounced wet and dry season, and semideciduous forest vegetation. The two sites are located in the Albrook Forest and at Chiva Chiva (see Figure II-1). The latter is in an open grass-covered area, four kilometers (2-1/2 miles) from the former, which is located within a forest with a relatively dense canopy about 10 meters thick and extending to about 27 meters above the ground and with an understory of shrubs and vines with greatest density at about 2 meters height.

Three satellite sites are currently being utilized for observation of soils and meteorological data. These are sites for which significant bodies of data had been gathered before the institution of the Data Base project, and at which instrumentation was already installed. Consequently it was considered desirable to maintain the sites under reduced observation schedules. Their locations are described below.

Proposed Sites

The establishment of paired sites is planned for the Atlantic side of the Canal Zone, where the significantly higher annual rainfall (130 in. average) with a less pronounced dry season produces vegetation with evergreen characteristics and forests with higher and denser canopies than on

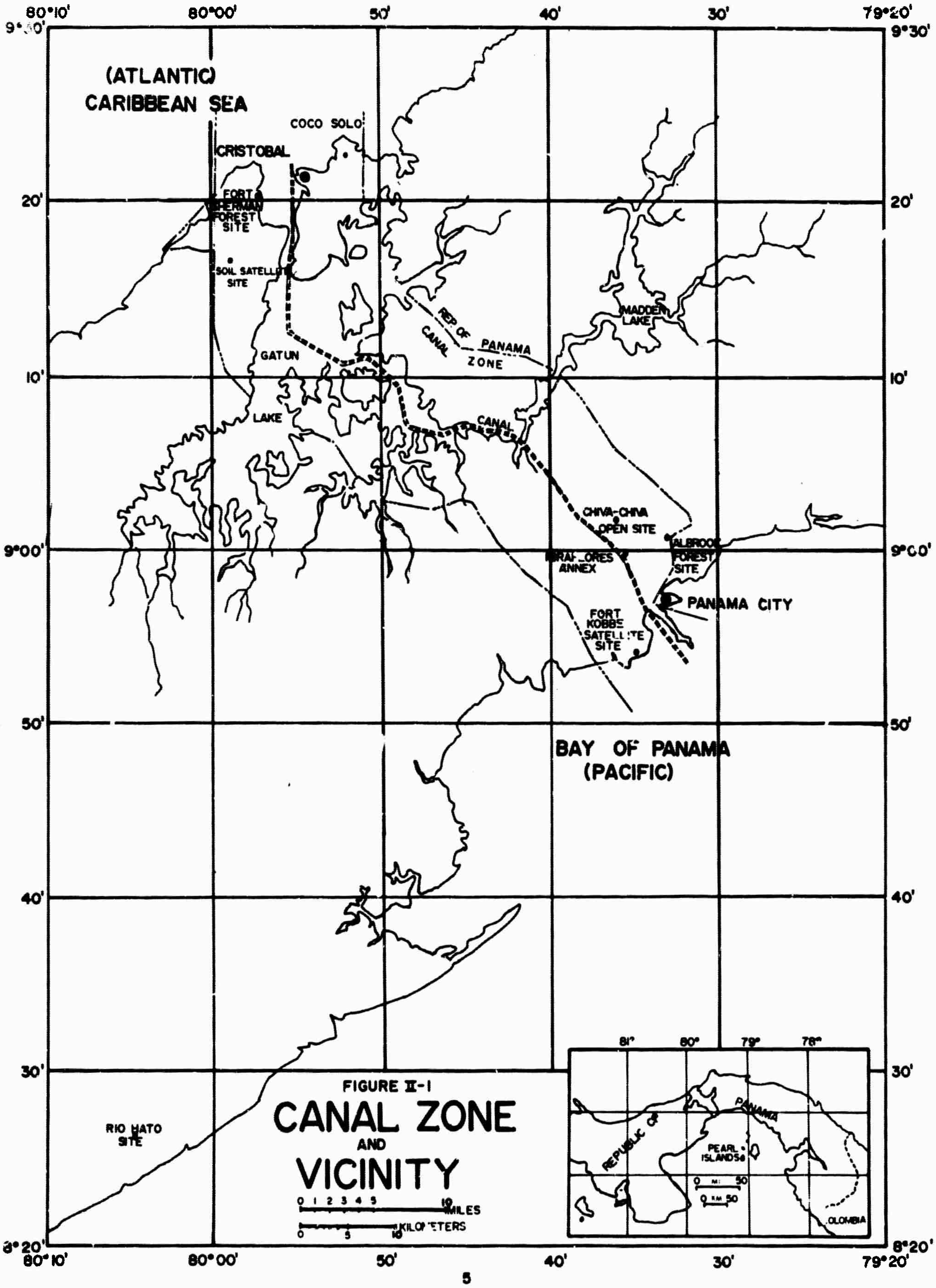


FIGURE II-1
CANAL ZONE AND VICINITY

the Pacific side. Two areas are under consideration: one in the vicinity of Fort Sherman, (military grid PV 144324), and the other in the Coco Solo Naval Ordnance Annex (military grid PV 245365).

The fifth main observational site has been planned for location on the Rio Hato Military reservation (approximate grid location, NV 970283) about 80 kilometers southwest of the Albrook sites (see Figure II-1). This is within a savanna (grassland) area with an annual rainfall of approximately 40 in. appreciably less than that at the Albrook area. Observations of some climatic factors were started at a location near the proposed site in 1965. These include rainfall, temperature, relative humidity, and wind speed and direction.

Site Descriptions

Albrook Forest Site

This site is located in the northeastern portion of the Albrook Air Force Base immediately adjacent to the Fort Clayton Military Reservation (military grid PV 602964). Elevations at the site range from 30 to 33 meters above sea level. (See Grid Orientor Map in Appendix C). The ground slopes very gently, approximately 4%, to the southeast. The nearly-level surface is broken only by a one-half to two-meter deep channel of an ephemeral stream running southerly across the eastern side of the test site. This stream enters the Rio Curundu which follows a southerly course, natural here in the upper stretches but canalized several kilometers downstream. The regional topography is characterized by rounded hills, with elevations up to 130 meters. The nearest lie about 400 meters to the east, and others 600 meters to the NW, the latter being part of a generally NE-SW trending line, with slopes ranging from about 10% to 50%. The site is located on a low, erosional terrace. The soil is a residual clay oxisol with a light-textured surface rich in organic matter. The parent material is an agglomeratic tuff (a pyroclastic rock with a fine grained matrix of volcanic ash with phenoclasts up to 1 cm in diameter).

The vegetation consists of many species of trees, shrubs, and vines, many of which are deciduous. The upper surface of the tree canopy occurs at 26 to 28 meters. The forest extends for several kilometers on all sides, except to the east of Rio Curundu where the large vegetation has been cleared. A gravel road provides access to a paved highway three kilometers distant. Figure II-2 is a view over the forest as seen from 30 meters above ground.

A walk-up tower, 46 meters high, fabricated from aluminum tubing, is located at the center of the site. Figure II-3 is a diagrammatic sketch of the towers showing the instrumentation array as generally followed at both main sites. Figure II-4 is a photographic view of the below-canopy portion of the tower.

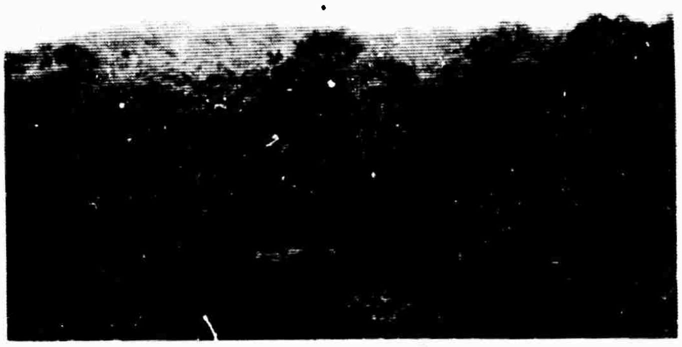


FIGURE II-2. ALBROOK FOREST, WESTWARD FROM TOWER AT 30 METERS

Two generators of 30 kw capacity provide the power required to operate the electrical instrumentation (see Figure II-5). They are located at the site entrance within a wire-protected enclosure. A concrete, air conditioned building for use of the round-the-clock observers, and in which the central components of the data acquisition and recording systems are located, is positioned on the perimeter of the site. (Figure II-5).

Figure II-6 shows the relative locations of the principal installations of the site, including the meteorological, soils, and biological instruments and devices. To minimize disturbance of the existing vegetation and soil surfaces, wooden walk-ways have been installed.

Chiva Chiva Open Site

This site is located in the northwestern section of the Fort Clayton Army Reservation (at PV 562979) approximately four kilometers west-northwest of the Albrook Forest Site. The location is in an open grass-covered area at approximately 30 meters elevation. The clearing extends about one-half kilometer to the northeast and in other directions for nearly one kilometer. Beyond the cleared area, a forest, like that at the Albrook site, prevails. The surface is nearly level, with a slight incline toward the southwest. Clay, oxisolic, residual soils, very sticky and plastic, comprise the surface mantle. The parent material, an agglomerate, is generally similar to that at the forest site. A tower, identical in structure to that at Albrook, is centrally positioned on the site. This tower carries a somewhat smaller number of instruments than the one at the Albrook Forest site (see Figure II-3). Two air conditioned vans are provided for the observers and the central components of instrumental recording systems. Electricity is supplied to the site by commercial line power. Figure II-7 is a plot of the principal installations at the site. Figure II-8 shows views of the tower and the vans at Chiva Chiva. Due to the open nature of the site,

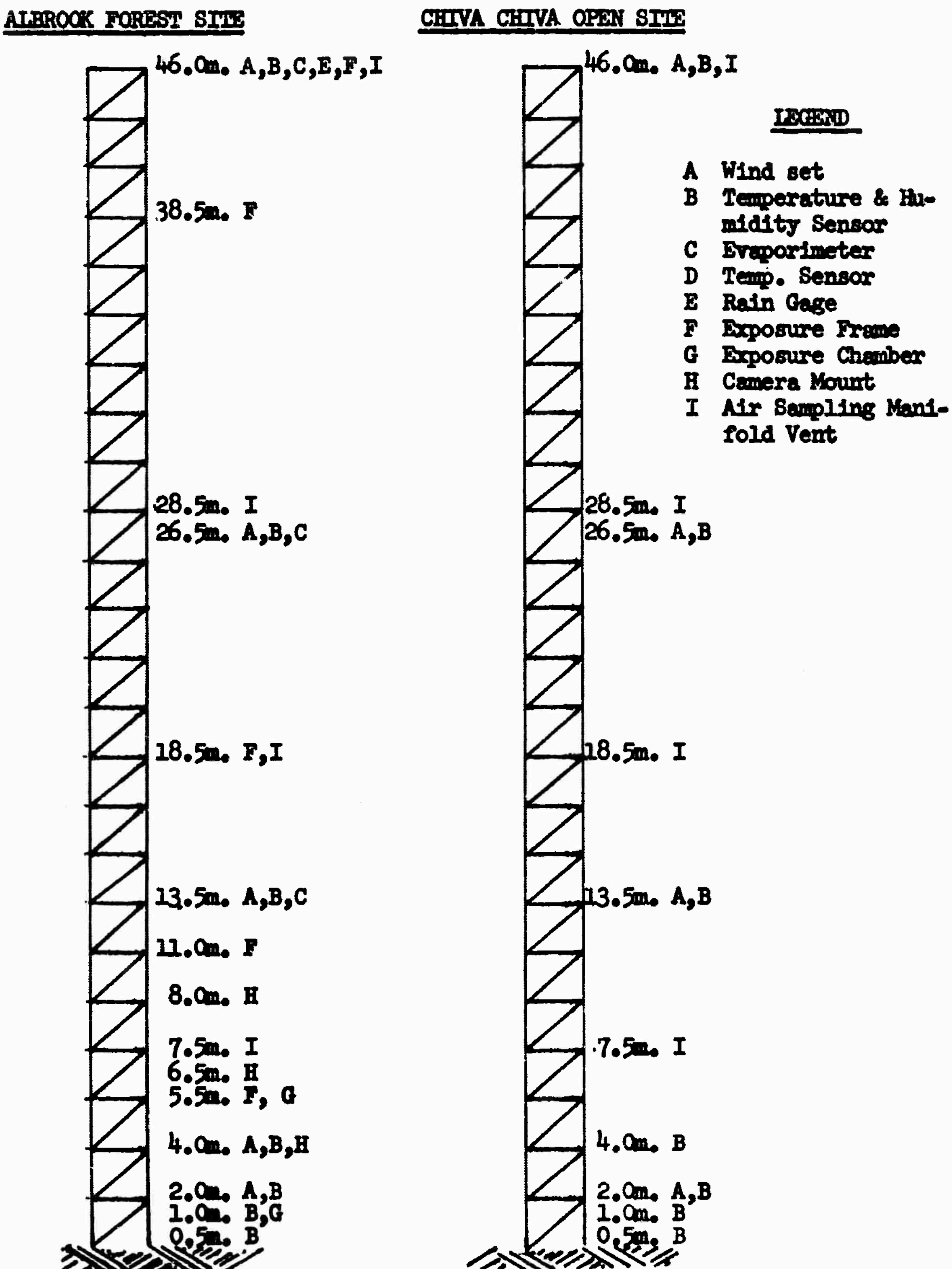


FIGURE II-3. INSTRUMENTATION ARRAY ON OBSERVATION TOWERS

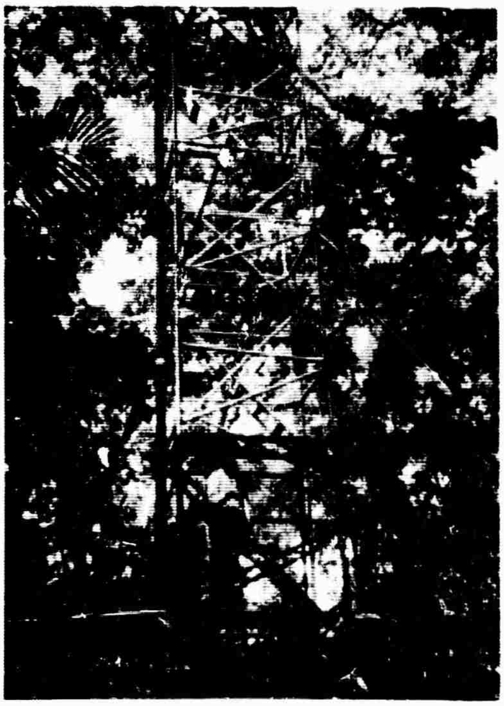
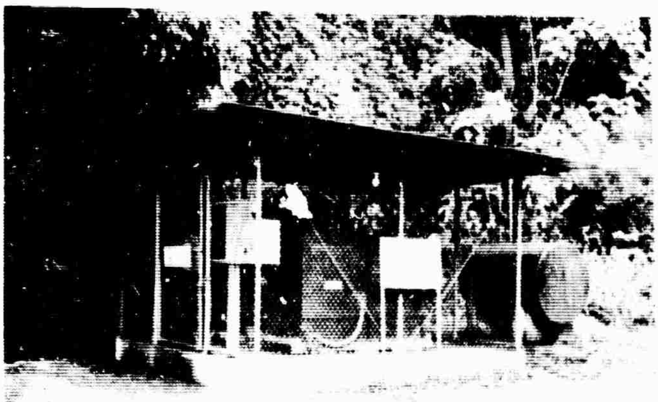


FIGURE II-4. TOWER AT ALBROOK FOREST SITE



Generator Shelter
at Entrance to Site

Observer and Recording
System Building

FIGURE II-5. INSTALLATIONS AT THE ALBROOK FOREST SITE

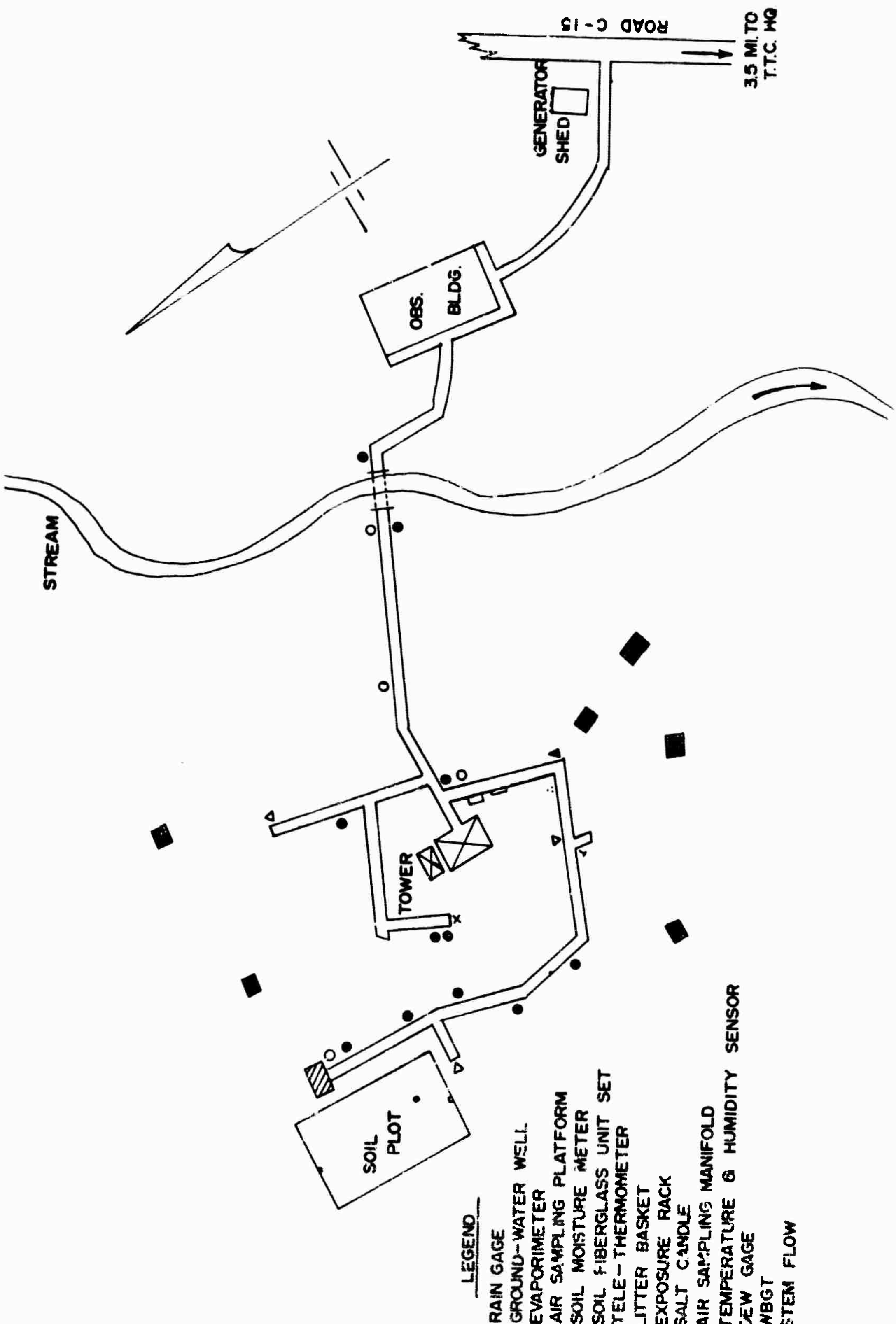


FIGURE II-6. ALBROOK FOREST SITE. GENERALIZED PLOT

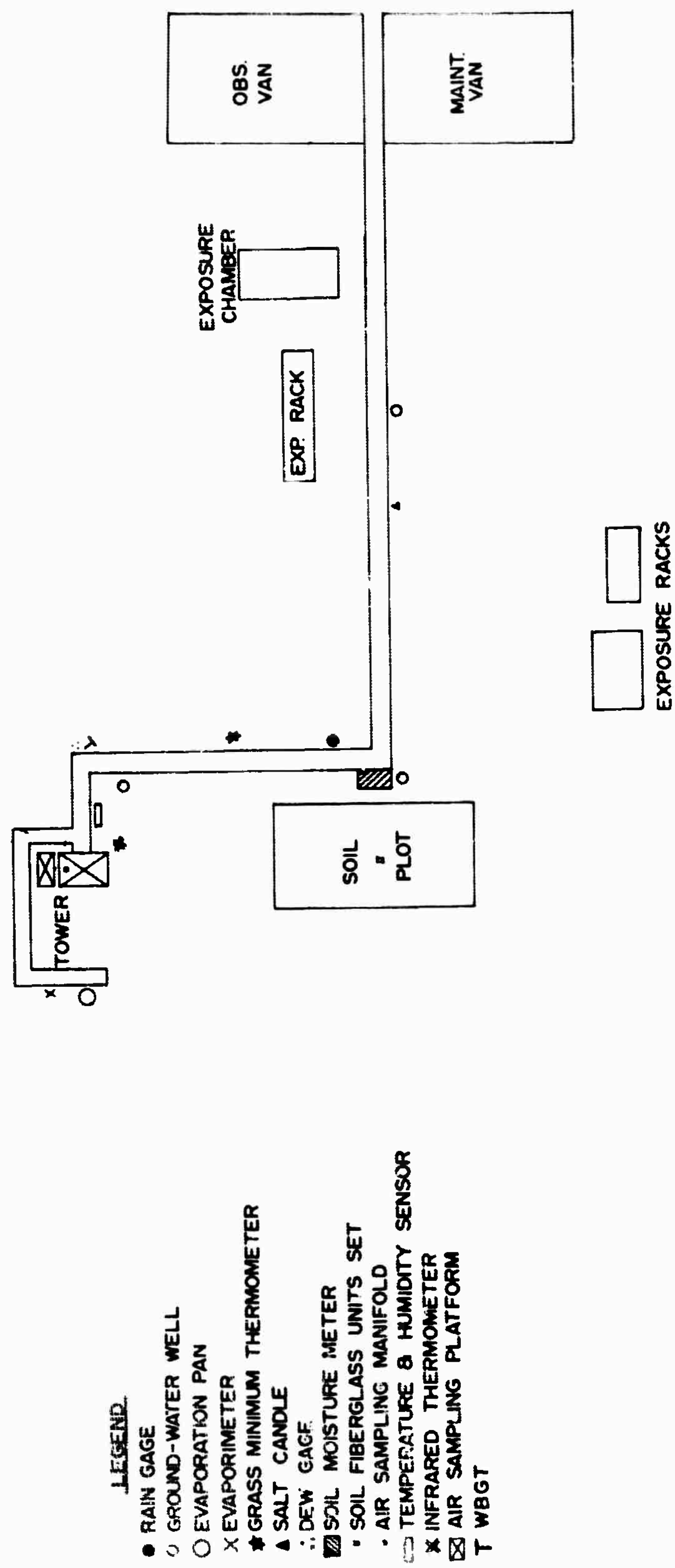


FIGURE II-7. CHIVA CHIVA SITE. GENERALIZED PLOT

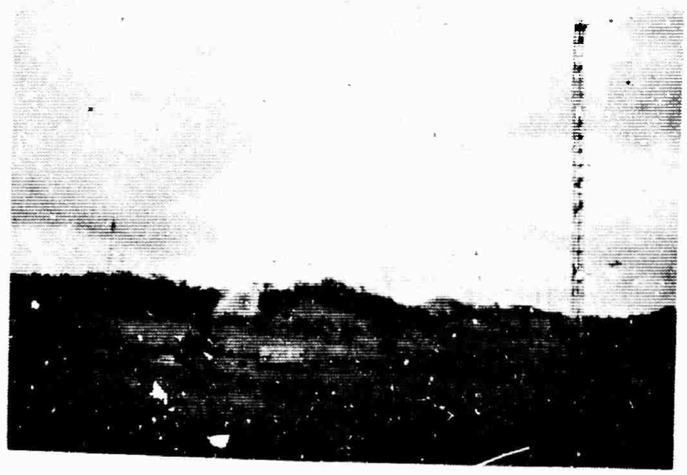


FIGURE II-8. CHIVA CHIVA SITE, OBSERVATION TOWER AND VANS

biological observations are not carried out as extensively as at the Albrook site. As at Albrook, wooden walk-ways are provided to prevent disturbance of natural conditions.

Albrook Satellite Site (Soil)

The Albrook soil satellite site is located approximately 400 meters southwest of the Albrook Forest site at PV 600960. The soil is a well-drained clay. The physical environment and topographic setting is similar to that of the main Albrook site. A cased ground-water well, with a water-level recorder, a hygrothermograph, and two recording rain gages (one in the open and another under the canopy) comprise the permanently installed equipment at this site.

Fort Kobbe Satellite Site (Soil)

The Fort Kobbe soil satellite site at PV 569848 (location shown on Figure II-1) is at an elevation of approximately 20 meters. The soil is a dark clay, very sticky and plastic. The topography is nearly flat, with slopes less than 2%. The vegetation is of secondary growth, with trees reaching a maximum height of about nine meters. Two rain gages, in the open and under the canopy; a hygrothermograph; and a cased water-well with a level recorder are installed at the site. Figure II-9 is a view of the site.

Fort Sherman Satellite Site (Soil)

This site is located within the Fort Sherman Army Reservation on the Atlantic side of the Canal Zone at PV 117261 (see Figure II-1), at an elevation of approximately 80 meters. The generally broken terrain slopes at about 40%. Soils are reddish brown, oxisolic clays, very sticky and plastic. The site is covered by a mature forest, with evergreen broadleaf species predominating. The same meteorological equipment is installed as at the other satellite sites.

FIGURE II-9. FORT KOBBE SOIL SATELLITE SITE

PART III. PROJECT ACCOMPLISHMENTS

General

During the reporting period observations have continued in the five study areas comprising the project. Microclimatic observations continue to provide the major bulk of the recorded data, and information concerning macrofauna has not been developed to the level planned. Observations of soil and hydrology conditions are approaching completion for the sites established on the Pacific side of the Canal Zone, though further analysis of the data is still required. The biological staff has been reinforced significantly, but the additions came at, or shortly after, the conclusion of the report period. Results of the increased capability in this area will be reflected in future reports of project progress.

Dissemination of Data

Monthly Microclimatic Summary

The publication of a series of microclimatic abstracts for monthly release is currently under way. These summaries will contain the basic meteorological data compiled each month. They are designed to provide factual knowledge, as well as cognizance of the existence of the data, to interested governmental agencies. Extensive distribution will be made (approximately 100 will be distributed initially). Additional copies will be available at the Defense Documentation Center.

This publication, entitled "Monthly Microclimatic Summary", is being printed as a pamphlet of approximately 30 pages. It consists of a brief introduction followed by the tabulated data. Table III-1 is a listing of the meteorological elements presented in the publication. Figure III-1 is an example of one of the tabular forms incorporated in the pamphlet.

TABLE III-1. ELEMENTS REPORTED IN MONTHLY MICROCLIMATIC SUMMARY

Monthly Means of Air Temperature by Hour
Monthly Ranges of Air Temperature by Hour
Monthly Means of Relative Humidity by Hour
Monthly Ranges of Relative Humidity by Hour
Monthly Means of Soil Surface Temperature by Hour
Monthly Means of Wet Bulb Temperature by Hour
Monthly Means of Barometric Pressure by Hour
Monthly Means of Precipitation by Hour
Monthly Totals of Precipitation
Monthly Ranges of Soil Surface Temperature by Hour
Monthly Ranges of Wet Bulb Temperature by Hour
Monthly Ranges of Barometric Pressure by Hour
Monthly Ranges of Precipitation by Hour
Monthly Means of Wind Speed by Hour
Monthly Ranges of Wind Speed by Hour
Relative Frequencies of Wind Directions (46 meters, Albrook)
Relative Frequencies of Wind Directions (4 meters, Albrook)
Relative Frequencies of Wind Directions (46 meters, Chiva Chiva)
Relative Frequencies of Wind Directions (4 meters, Chiva Chiva)
Summary of Elements with Non-Hourly Frequencies of Observation:
  WBGT - (Albrook)
  Evaporation - (Albrook)
  Precipitation - (Manual gage network, Albrook)
  Precipitation - (Stem Flow, Albrook)
  WBGT - (Chiva Chiva)
  Evaporation - (Chiva Chiva)
  Minimum Grass Temperature - (Chiva Chiva)
  Maximum Temperature - (Albrook Satellite site)
  Minimum Temperature - (Albrook Satellite site)
  Maximum Relative Humidity - (Albrook Satellite site)
  Minimum Relative Humidity - (Albrook Satellite site)
  Precipitation - (Albrook Satellite site)
  Maximum Temperature - (Fort Kobbe, Satellite site)
  Minimum Temperature - (Fort Kobbe, Satellite site)
  Maximum Relative Humidity - (Fort Kobbe, Satellite site)
  Minimum Relative Humidity - (Fort Kobbe, Satellite site)
  Precipitation - (Fort Kobbe, Satellite site)
  Maximum Temperature - (Fort Sherman, Satellite site)
  Minimum Temperature - (Fort Sherman, Satellite site)
  Maximum Relative Humidity - (Fort Sherman, Satellite site)
  Minimum Relative Humidity - (Fort Sherman, Satellite site)
  Precipitation - (Fort Sherman, Satellite site)

SUMMARY OF METEOROLOGICAL OBSERVATIONS

HOURLY DATA

NOVEMBER 1966

Exposure: Site	Exposure: Level	Monthly Means of Air Temperature by Hour (°F) 01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Monthly Summary: No. of Obs.	Min.	Mean	Max.
Albrook (Forest site)	46.0 m	74.0	73.8	73.6	73.5	73.5	73.4	74.3	76.1	78.2	79.6	80.7	80.9	80.4	79.8	79.3	78.2	77.1	75.8	75.2	74.8	74.5	74.3	74.3	74.1	715	71.7	76.2	85.6
	28.5 m	73.8	73.6	73.4	73.2	73.1	73.1	74.5	76.8	79.2	81.1	81.9	81.7	81.4	80.4	80.2	79.1	77.7	76.2	75.4	75.1	74.6	74.4	74.2	74.0	718	69.2	76.6	88.1
	23.5 m	73.8	73.8	73.4	73.2	73.2	73.1	74.6	77.1	79.8	81.7	82.7	82.3	82.0	81.0	80.6	79.6	77.9	76.2	75.3	75.0	74.5	74.4	74.2	73.9	718	69.7	76.8	89.9
	13.5 m	73.6	73.4	73.3	73.1	72.9	72.8	73.6	75.9	78.0	79.6	80.8	80.9	81.0	80.2	79.5	78.6	77.4	76.0	75.1	74.7	74.3	74.2	73.9	73.7	720	68.4	76.1	86.9
	8.0 m	73.5	73.2	73.2	73.0	72.9	72.7	73.5	75.4	77.8	79.4	80.6	80.8	80.8	80.1	79.4	78.5	77.3	76.0	74.9	74.6	74.2	74.0	73.8	73.5	720	69.9	76.0	86.3
	4.0 m	73.1	72.9	72.9	72.6	72.5	72.3	73.2	75.6	77.5	79.1	80.3	80.5	80.2	79.4	78.7	77.8	76.8	75.5	74.5	74.2	73.8	73.6	73.4	73.2	718	69.5	75.6	85.2
	2.0 m	73.1	73.0	72.9	72.6	72.5	72.3	73.2	75.3	77.2	78.8	79.9	80.1	79.9	79.3	78.7	77.8	76.7	75.5	74.5	74.2	73.8	73.6	73.5	73.2	718	69.5	75.5	85.0
	1.0 m	73.4	73.3	73.1	73.0	72.8	72.6	73.2	75.1	77.0	78.3	79.4	79.6	79.6	79.5	78.8	77.7	76.7	75.5	74.6	74.6	74.1	73.9	73.7	73.5	720	70.0	75.6	85.0
	0.5 m	73.5	73.4	73.3	73.2	73.0	72.9	73.3	74.8	76.5	77.7	78.6	78.9	79.0	78.7	78.5	77.5	76.8	75.8	74.9	74.6	74.2	74.0	73.8	73.6	720	69.8	75.4	83.5
[illegible] (Open site)	46.0 m	74.1	73.8	73.6	73.5	73.5	73.4	74.0	75.9	78.4	79.8	80.7	30.8	80.6	80.8	79.9	79.0	77.5	76.4	75.6	75.3	74.9	74.7	74.5	74.2	696	71.1	76.5	85.6
	28.5 m	This level was not instrumented for air temperature at this time																											
	26.5 m	74.1	73.7	73.6	73.5	73.4	73.3	74.0	76.0	78.5	80.0	80.8	60.9	80.7	80.7	80.0	79.1	77.9	76.7	75.8	75.3	74.9	74.7	74.5	74.2	720	70.8	76.5	86.4
	13.5 m	73.9	73.6	73.4	73.3	73.2	73.2	73.8	76.2	78.7	80.4	81.3	81.4	81.2	81.0	80.3	79.4	78.0	76.8	75.8	75.3	74.9	74.6	74.4	74.0	716	70.6	76.6	87.5
	6.5 m	This level was not instrumented for air temperature at this time																											
	4.0 m	73.3	73.2	72.9	72.9	72.9	73.0	74.4	77.1	80.0	81.6	82.3	82.5	82.0	81.8	81.3	80.2	78.4	76.7	75.7	75.1	74.7	74.2	74.0	73.5	715	69.0	76.8	88.8
	2.0 m	73.1	72.9	72.7	72.7	72.7	72.7	74.5	77.5	80.2	81.7	82.4	82.7	82.3	82.0	81.1	80.2	78.2	76.4	75.4	74.8	74.4	73.9	73.7	73.2	715	68.5	76.7	89.4
	1.0 m	73.4	73.1	72.9	72.9	72.7	72.3	74.4	77.7	81.0	82.8	83.2	83.6	83.1	82.7	81.4	80.1	78.2	76.1	75.1	74.9	74.5	74.1	73.8	73.6	719	68.0	77.0	91.0
	0.5 m	73.5	73.2	73.0	72.9	[illegible]	72.8	74.0	76.9	80.0	82.6	84.0	83.9	84.2	83.5	81.9	80.3	78.7	76.5	75.4	74.8	74.4	74.1	73.9	73.7	720	68.9	77.1	95.5

FIGURE III-1. EXAMPLE OF TABULATED METEOROLOGICAL DATA IN MONTHLY MICROCLIMATIC SUMMARY

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PART IV. CLIMATE*

Introduction

This subtask of the Data Base project is designed to determine the microclimatic characteristics of the observation sites, with particular reference to other environmental studies being conducted concurrently. Measurements of climatic elements are made through the vertical profiles by exposing sensors at several selected levels on the 46-meter towers together with an array placed at the ground level at the two main sites, Albrook Forest and Chiva Chiva (see Figures II-2, -5, and -6). All determinations are made at scheduled time intervals, and like measurements are made simultaneously, at the forest and open sites. The simultaneity and continuity of measurements at the Data Base sites makes possible the definition in precise terms of the areal and temporal variations of the humid tropical climate as exhibited at the two sites.

Instruments used for data acquisition are selected on the basis of ability to withstand the severe tropical environment while producing reliable results. A continuing training program is conducted to obtain maximum efficiency from the observers.

Observations

Meteorological observations of the following elements have been made: Clouds, Dew, Evaporation, Humidity, Precipitation, Pressure, Special phenomena, Stem flow, Temperature, Visibility, Wet-bulb-globe temperature, Wind speed and Wind direction. Temperature, humidity, and wind measurements are taken at eight levels on the tower: 0.5, 2, 4, 8 meters, and at the levels of the base and top of the upper canopy, two meters above the canopy, and the top of the tower (46 meters). Precipitation is measured above the canopy and at the ground level at the forest site. The ground level measurements include both direct canopy penetration and stem flow. All other measurements, made at both sites, are made at the most advantageous exposures. Measurements of radiation and sunshine which have not been made to date, will begin with the installation of the Meteorological Data Acquisition and Recording Systems (MDARS), described below.

The full range of climatic elements has been observed at the two main sites, as nearly as possible, while only limited data were observed at the Rio Hato savanna site. Temperatures, humidities, and rainfall were measured at the three satellite soil sites. The types and frequencies of meteorological observations made at each site are summarized in Table IV-1.

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* These introductory and descriptive sections of Part IV have been prepared by Mr. Michael A. Fradel, Meteorological Technician.

TABLE IV-1. LOCATION OF SENSORS AND FREQUENCY OF OBSERVATIONS

Element	Sfc	0.5	1.0	2.0	4.0	8.0	13.5	26.5	28.5	46.0	Frequency
					Height (meters)						
Temperature:											
Dry Bulb	2	2	1	2	2	3	2	2	3	2	Hourly*/Continuously
Wet Bulb	-	2	-	2	2	-	-	-	-	-	Hourly*/Continuously
Grass Minimum	4	-	-	-	-	-	-	-	-	-	Once Daily
WBGT Index	-	-	2	-	-	-	-	-	-	-	Hourly (0600-1900 EST)
Relative Humidity	-	2	1	2	2	3	2	2	3	2	Hourly*/Continuously
Barometric Pressure	-	-	2	-	-	-	-	-	-	-	Continuously
Evaporation	2	-	-	-	-	-	-	3	-	3	Once Daily
Precipitation:											
Recording Gage	-	-	1	-	-	-	-	-	-	3	Continuously
Manual Gage	-	-	3	-	-	-	-	-	-	-	4 Times Daily
Stem Flow	-	-	3	-	-	-	-	-	-	-	4 Times Daily
Wind:											
Direction	-	-	-	-	5	-	-	-	-	2	Continuously
Speed	-	-	-	2**	5	-	2**	2**	-	2	Hourly**/Continuously

1. All sites
2. Albrook and Chiva Chiva
3. Albrook only
4. Chiva Chiva only
5. Main sites and Rio Hato

* Observation made with sling psychrometer when recorders are inoperative.

** Hourly.

Instrumentation

Current Instrumentation

The instruments used for making the meteorological measurements have been largely of standardized types: (see previous Semiannual Report,[(1)*] pp. 17-19) standard rain gages for precipitation, various standard types of hygrothermographs and psychrometers for temperatures and humidities (see Figure IV-1), Belfort and GMQ/12 wind sets for winds, and a standard evaporation pan. Although the hygrothermographs and the wind sets are adequate instruments under normal conditions, their exposure to the tropical environment necessitates considerable maintenance effort in order to obtain data of maximum continuity and accuracy. This applies to any instrument employing the strip chart recording technique. To counteract these deficiencies in instrumentation, the MDARS was specifically designed to operate in the severe tropical environment. The strip chart recording technique has been eliminated; the active electronics are being placed in air-conditioned buildings, to the greatest extent possible; and the sensors are of advanced design to minimize effects of environmental exposure. Consequently, a higher degree of accuracy in the data can be attained and the maintenance effort greatly reduced.

To further improve techniques and instrumentation, infrared thermometers have been added to measure soil surface temperatures (Figure IV-2). An experimental evaporimeter consisting of a Livingston atmometer and a modified Piche evaporimeter (the edge of the disc has been sealed) was placed next to the standard evaporation pan (see Figure IV-3) to establish correlations between the various instruments. The rain gage network, for the measurement of rain penetration through the canopy, will be increased to improve the determination of the representative amount of rainfall reaching the forest floor. A detailed discussion of the experiment with infrared thermometers is presented in a following section. Results of the experiment with the evaporimeters will be presented in future reports.

Future Instrumentation

A contract was awarded on 21 December 1966 for the procurement of two complete and separate units of an automatic meteorological data acquisition and recording system (MDARS). Each system consists of meteorological sensors mounted on the observation towers, a means for converting the sensor output to measurable quantities, a measuring system, and a digital system which ultimately punches the quantified parameter on paper tape in the form of an eight-channel binary coded decimal code. To make their operation entirely automatic, timing and control devices will be incorporated in the systems. A control panel will permit all functions of the system to be controlled manually. Any sensory input can be selected, displayed, and/or recorded, individually.

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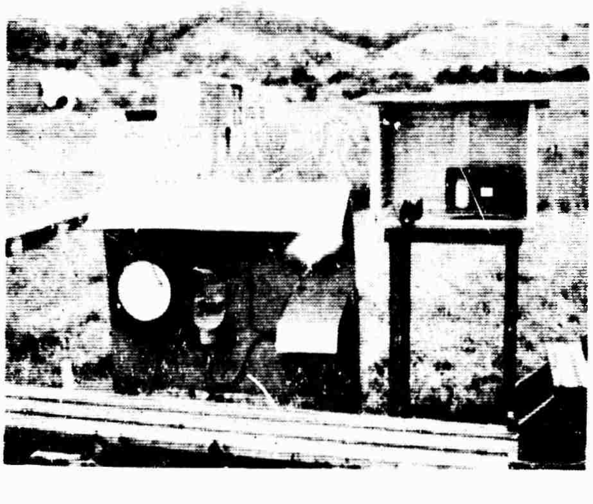
* References listed at the end of this report.

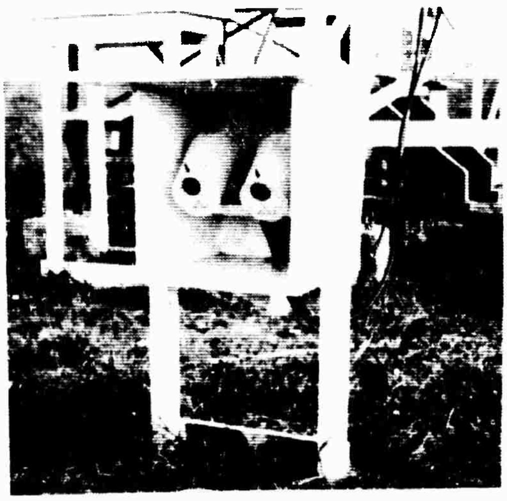
Weighing anu Recording Rain Gage
at Chiva Chiva Site

Manual Clear-Vu Rain Gage at
Albrook Forest Site

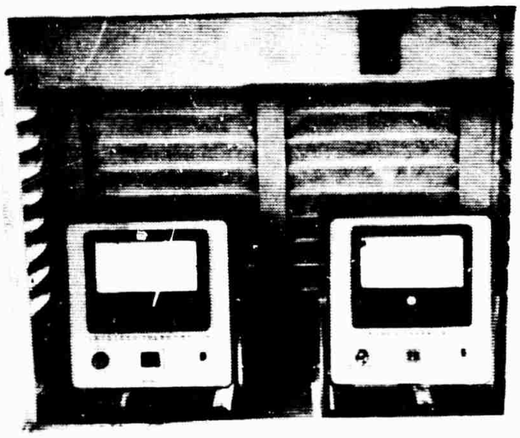


Honeywell-Brown and Bendix
Hygrothermographs and Bendix
Psychron at Chiva Chiva Site

FIGURE IV-1. VIEWS OF INSTALLED INSTRUMENTS

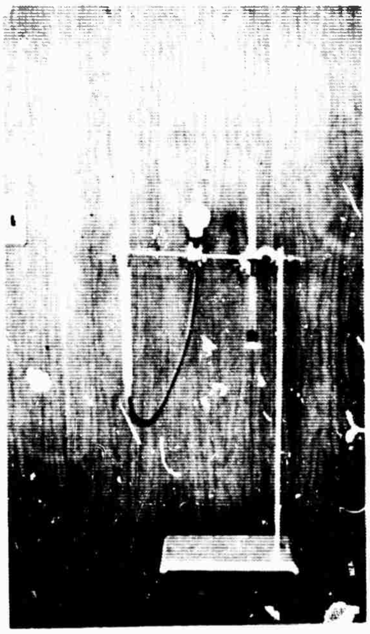


Infrared Thermometer Sensors

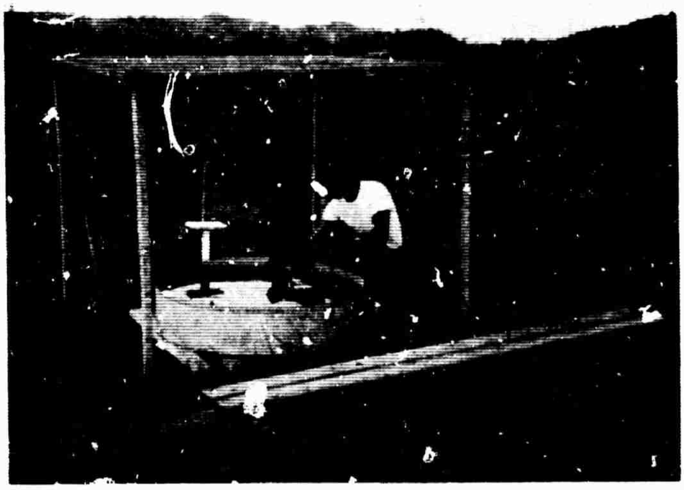


Infrared Thermometer Indicators

FIGURE IV-2. INFRARED THERMOMETERS



Livingston Atmometer and Modified Piche Evaporimeter



Standard Evaporation Pan with the Piche Evaporimeter on the Left

FIGURE IV-3. EVAPORATION MEASURING INSTRUMENTS

Each system provides five of each of the following sensors: wind speed, wind direction, dry bulb and wet bulb temperatures. The systems will employ circuitry of modular design so that additions may be made with minimum modification. At the time of field installation the addition of the following sensors is planned: sunshine, rain gage (tipping bucket), pyranometer, radiometer-net exchange, and radiometer-total hemispheric. A tape reader and automatic typewriter combination will be included as part of the system, which will serve the purpose of monitoring data at the site, as it is being received.

The systems are scheduled for delivery and installation in mid-1967. Figure IV-4 shows some of the components of the MDARS. Figure IV-5 gives a view of the internal circuitry of the wind transmitters. Figure IV-6 pictures some of the internal electronics of the digital registers. Figure IV-7 is a block diagram of the MDARS.

Special Maintenance Problems

The maintenance and the calibration of instruments subjected to the degradational effects of the humid tropic environment continues to be a major problem in the operational continuity of the Data Base project.

To prolong the time between failure and to increase the service life of the recording-type instruments, all charts are exposed to the ambient atmosphere prior to use, pens are cleaned weekly, hair elements (of the hygrothermographs) are replaced frequently -- often weekly, the entire assembly is cleaned monthly, and the casings are repainted at least every six months. Calibration checks have been increased to five times per day. The wind measuring instruments require frequent overhaul. These instruments are completely disassembled and thoroughly cleaned at least once each month. The phenolic resin tube sockets supplied with the GMQ-12 wind sets deteriorate rapidly in the tropical environment; their replacement by ceramic sockets has prolonged the life of this component.

Another serious maintenance problem at the Albrook Forest site is created by the use of field-type generators as a power source. Many cases of generator failure have occurred in which the generator required field maintenance. This necessitates removal of the malfunctioning generator from the operating site to the maintenance shop and the installation of a replacement. Since two on-site generators are necessary to afford a continuous power supply (generators are alternated each 24 hours), the supply problem alone has proven difficult. Moreover, the ready availability of at least two additional generators is desirable in the event, which has often occurred, that both on-site generators become inoperative during the same period. This problem could be avoided by utilizing a commercial power line. However, the distance of the site from the nearest transformer facility precludes installation of a separate power line to the site because of fund limitations. A possible solution for the future would be the use of a commercial unit rather than the government issued field-type generator. This possibility is being investigated.

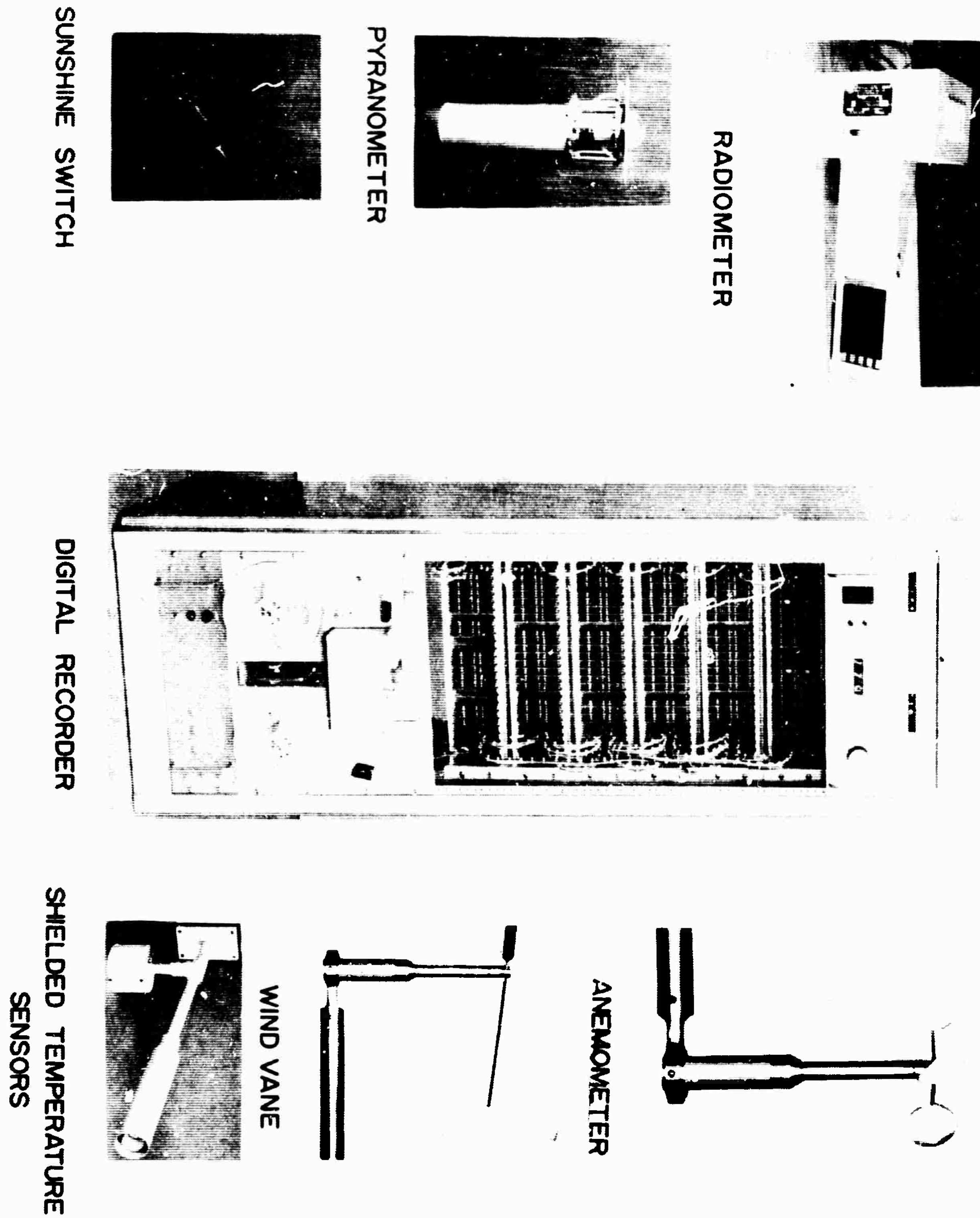
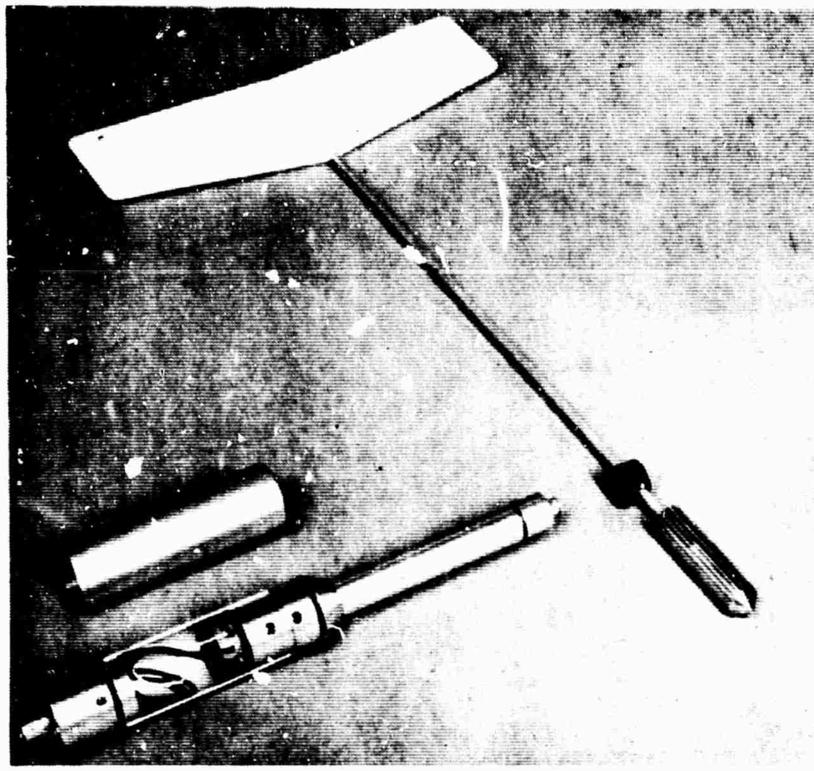
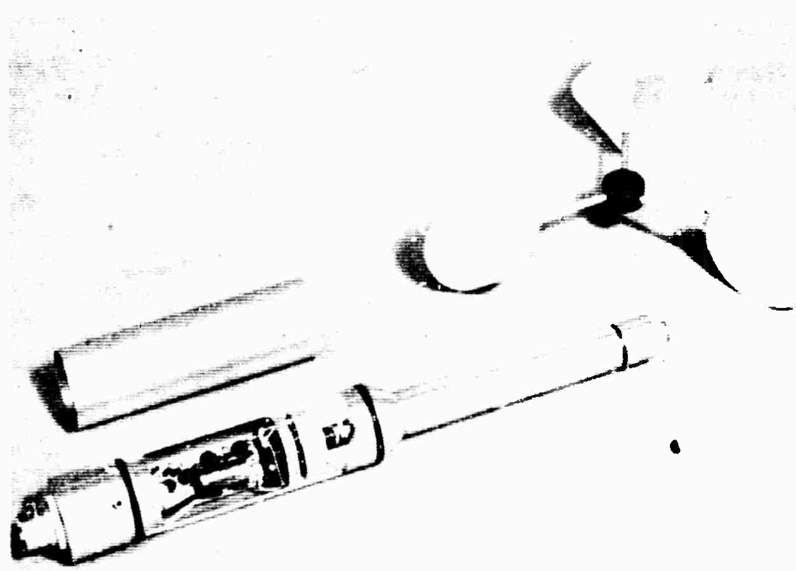


FIGURE IV-4. SOME COMPONENTS OF THE METEOROLOGICAL DATA ACQUISITION AND RECORDING SYSTEMS



WIND DIRECTION TRANSMITTER



WIND SPEED TRANSMITTER

FIGURE IV-5. WIND SENSORS, SHOWING INTERNAL CIRCUITRY

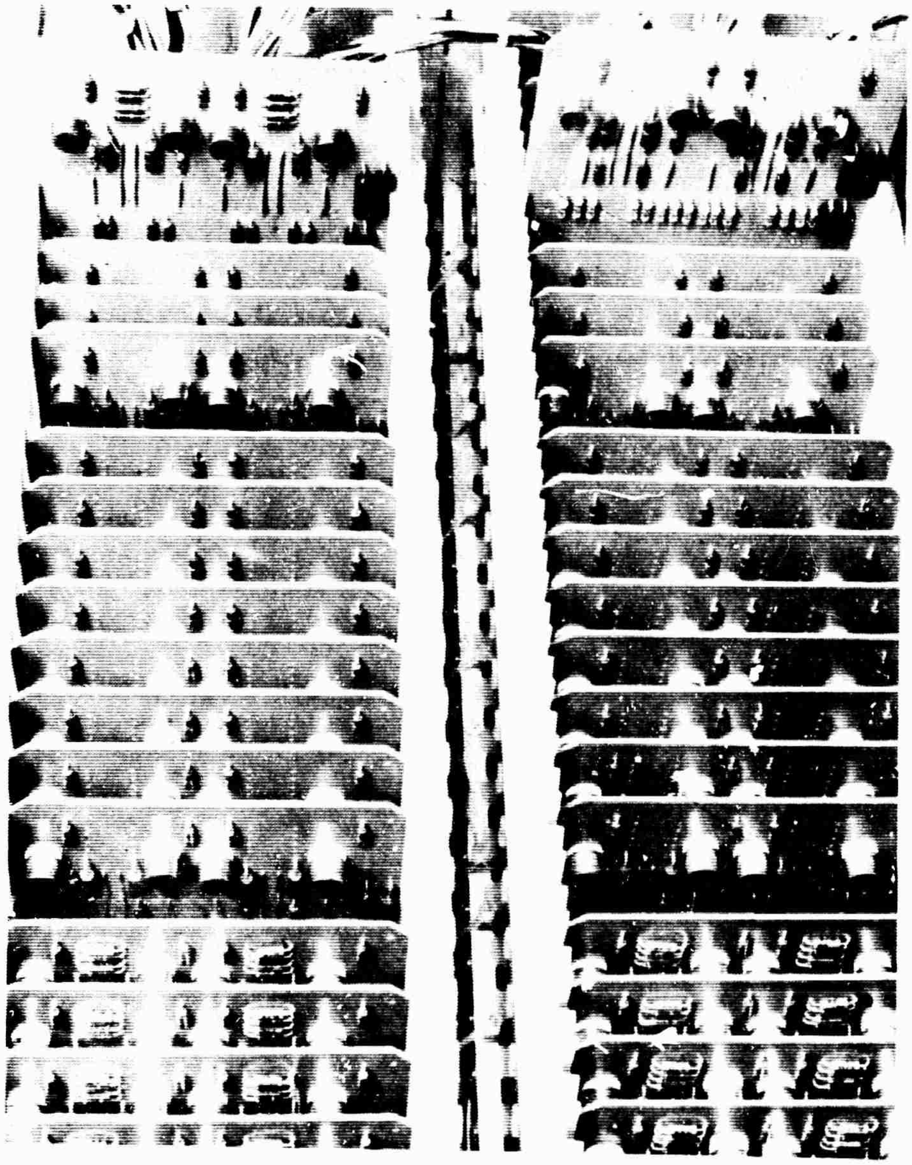


FIGURE IV-6. DIGITAL REGISTERS

FIGURE IV-6. DIGITAL REGISTERS

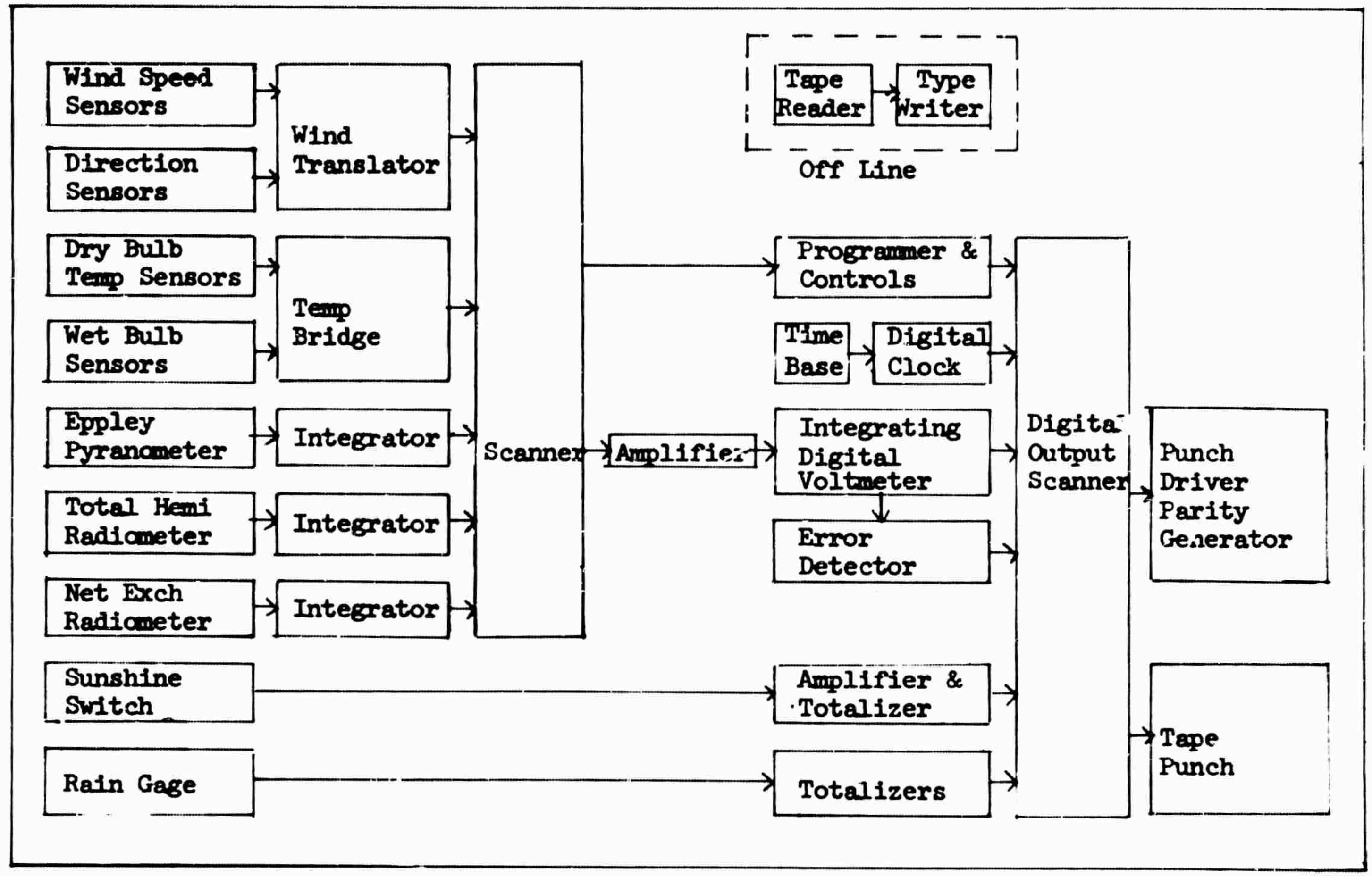


FIGURE IV-7. BLOCK DIAGRAM OF METEOROLOGICAL DATA AND RECORDING SYSTEM

Data Reduction and Storage

The data generated through the climate subtask represent the largest single body of data within the project. Approximately 64,000 observations are made each month. All of these observations, except wind direction and surface observations (approximately 25,000), have been entered on punch cards. Prior to entry on cards, the data are reduced to hourly values, as appropriate, from the data source forms; i.e., strip charts and log forms. The raw data are screened, verified for accuracy and validity, and then processed by a computer. The print-out exhibits the hourly values as well as the daily and monthly means and extremes. Examples of the data source forms and the monthly summaries derived from the computer print-outs may be seen in the previous Semiannual Report(1). The print-outs are used by the Tropic Test Center to make analyses of the various elements and correlations with other factors being observed. All punch cards, raw data, and data-source forms are stored in the Tropic Test Center Technical Library Annex at the Miraflores Laboratory. These data may be made available to any authorized agencies for analysis. As an example of such usage, the US Army Natick Laboratories is currently planning a rainfall study which will utilize specific types of data to be selectively retrieved from the data bank and presented on magnetic tape. Natick will be requested to provide the Tropic Test Center a duplicate of this tape and the results of the study.

The total number of individual meteorological observations recorded and stored during the reporting period, 1 September 1966 through 28 February 1967, is summarized in Table IV-2.

TABLE IV-2. TOTAL NUMBER OF METEOROLOGICAL OBSERVATIONS FOR PERIOD 1 SEPTEMBER 1966 THROUGH 28 FEBRUARY 1967

	Albrook	Chiva Chiva	Rio Hato,	Albrook Soil Site	Ft. Kobbe Soil Site	Ft. Sherman Soil Site	TOTAL
Dry Bulb Temperature	42,638	34,768	4,227	292	346	336	82,607
Wet Bulb Temperature	13,032	12,948	--	-	-	-	25,980
Relative Humidity	30,219	30,208	4,167	292	346	336	65,568
Wind Speed	15,731	21,178	680	-	-	-	37,589
Wind Direction	15,731	15,731	680	-	-	-	32,142
Evaporation	539	380	--	-	-	-	919
Rain Gage (Recording)	17,207	4,341	4,344	4,472	7,304	6,776	44,444
Rain Gage (Manual)	5,820	--	--	-	-	-	5,820
Stem Flow	2,226	--	--	-	-	-	2,226
Barometric Pressure	4,344	4,344	--	-	-	-	8,688
WBGT	10,156	10,152	--	-	-	-	20,308
Surface Observations	--	56,940	--	-	-	-	56,940
TOTALS	157,643	190,990	14,098	5,056	7,996	7,448	383,231

Data Analysis

Analyses of the meteorological data acquired under the project, as well as of the methodology for its acquisition, are carried out, as time permits, in order to increase the utility, significance, accuracy, and validity of the measurements. In line with this objective, the sections below are presented.

Diurnal Temperature Variation in Forest and Open Sites*

Introduction

Microclimatic data will be summarized by monthly averages and totals, as described on p. 16, for dissemination to interested agencies. The original raw data will also be available to research workers, either in punch card or tape form. The analysis presented here is an example of how the original data can be applied. Though temperature variations in the tropics are less pronounced than at higher latitudes, definite variational patterns do exist, and these are assumed to affect propagation of sound and radio waves and the dispersion of microorganisms, gases, and other materials. In this study two simple weather patterns, which occurred in September 1966, have been singled out for analysis: days without rain at both the open and forested sites; and days with rain at both sites. The analysis utilizes the readings taken each hour, on the hour.

Analytical Method

There were seven days in September 1966 without any rain at Chiva Chiva and Albrook, and ten days with rain at noon at both stations. Averages of such small samples are usually somewhat irregular because of incidental variations and non-systematic observational errors. To smooth the irregularities without eliminating significant details, the data were submitted to harmonic analysis, from which new sets of data were produced by summing the first harmonics. Since the temperature pattern of days with rain is rather complicated, the first eight harmonics were used for such days, while only the first four harmonics make up the smoothed data for the days without rain. In addition, the constituents of each harmonic were smoothed vertically by plotting the values of the same harmonic as obtained for each level on graph paper as a function of height over ground, and by drawing a smooth curve in such a way that the differences between the curve and the plotted values were reasonably small.

This procedure permits the computation of the temperatures for any desired time of the day and for any level between 50 cm and 46 m. However, with exception of the 8-meter level in Chiva Chiva (for which no records exist) the smoothed temperatures were computed only for the levels and the times (full hours) for which actual observations exist. No smoothing has

* This section has been prepared by Dr. Wilfried H. Portig, Research Meteorologist.

been applied in those cases in which all thirty days in the month have been considered.

Presentation

The entire bulk of data is presented in three different forms in Figures IV-8, -9, and -10. Each figure shows height above ground as the ordinate, which is plotted on a logarithmic scale in order to better show the relatively larger variations near the ground. While this seems to be the best way to present the data for the Chiva Chiva open site, there are unavoidable shortcomings with respect to the treetop level at the Albrook Forest site (26.5 m). To a certain extent the deficiencies of presentation at that level are justified by the fact that there are no other observations close to 26.5 m which might provide more details of the temperature distribution near the upper surface of the canopy. A wavy line in the Albrook graphs is to remind the reader that 26.5 m is just above the general treetop level.

Figure IV-8 shows the smoothed mean temperature of the days without rain at both stations (upper part of the figure), and those with rain around noon at both stations (lower part). The diagrams on the left side refer to Albrook Forest, those on the right to the Chiva Chiva open site.

Figure IV-9 has the same arrangement as Figure IV-8. It shows the changes of temperature from one hour to the next by means of isallotherms, i.e., lines of equal temperature change.

Figure IV-10 is another presentation of the same data displayed in the lower part of Figure IV-8. For selected hours the vertical distribution of temperatures is shown in form of curves. For legibility, the figure is broken down into the periods from midnight to noon, and from noon to midnight. The marginal curves of 2400 and 1200 appear in either part of the figure.

Discussion

General. The simple basic concept of the diurnal temperature variation, "warm at noon, cool at night", is modified in several aspects. Three parts of Figure IV-8 show that the highest temperatures occur approximately at noon (astronomical noon occurs at 12:10 in September), i.e., two or three hours earlier than seems to be normal in most of the world. This is the consequence of two effects which are merely different expressions for the same weather development. The first is the increase of cloudiness which begins at sunrise for low clouds, and at an earlier hour for total cloudiness. On those seven days without rain at both observation sites the total cloudiness increased from 0.6 at 0400 hours to 0.9 at 1000 and from there, after a slight dip to 0.8 at 1300, to 1.0 at 1700 hours. Such a strong cloud development necessarily decreases the amount of effective solar radiation. The other factor that prevents further rise of temperature after midday is the development and discharge of thunderstorms in the vicinity of,

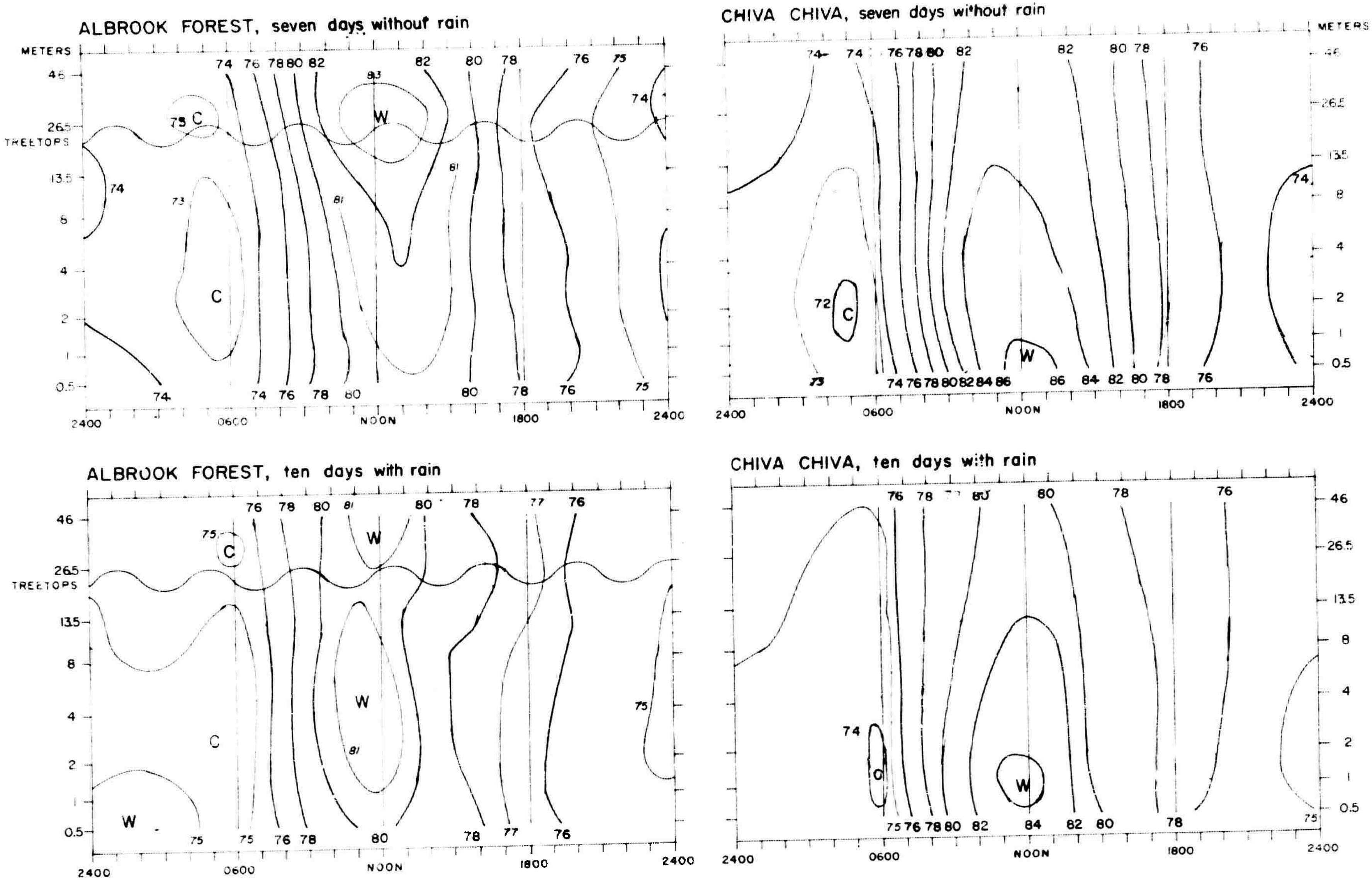


FIGURE IV- 8 SMOOTHED MEAN TEMPERATURES (F)

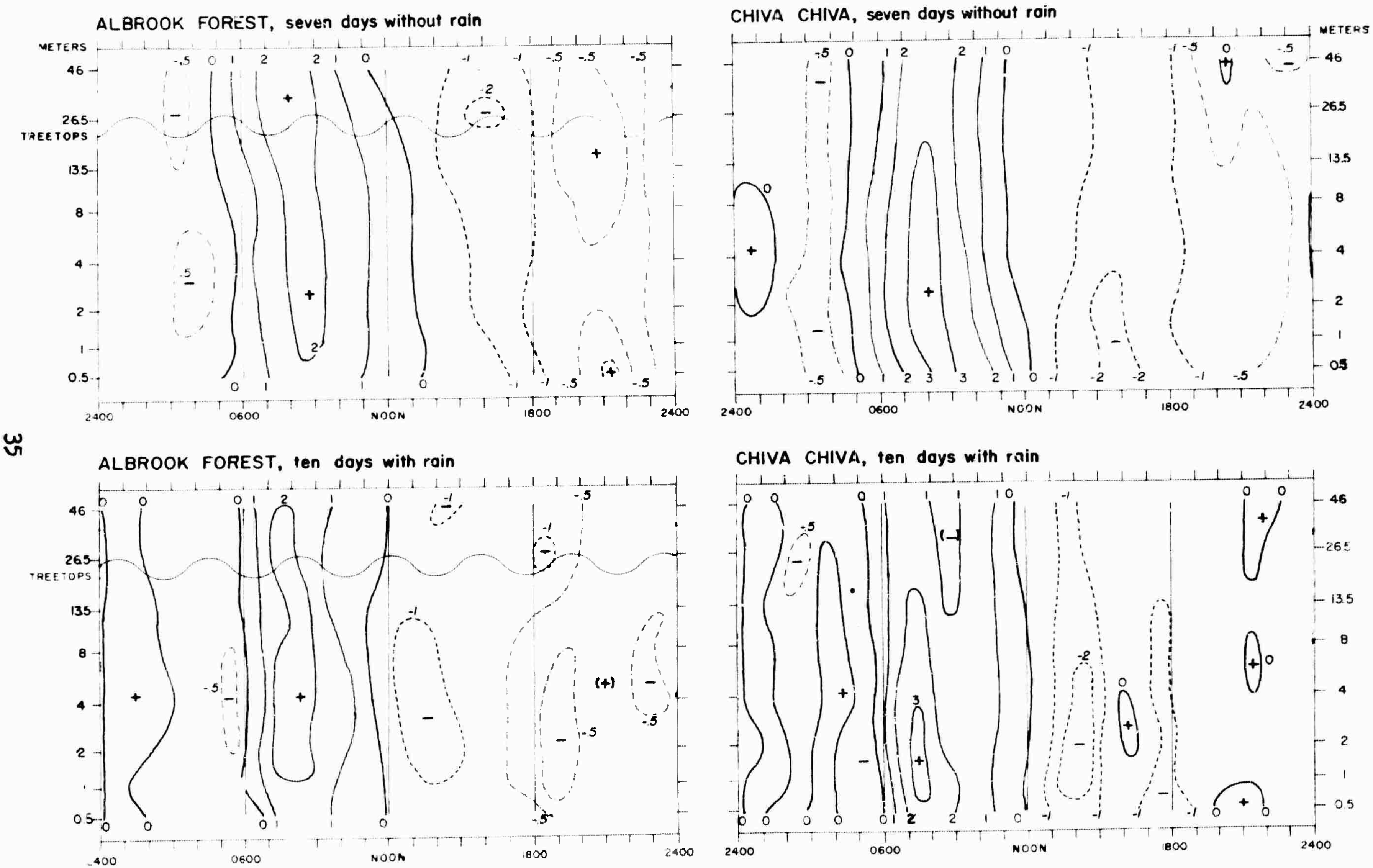


FIGURE IV-9. HOURLY TEMPERATURE CHANGES (F/hr)

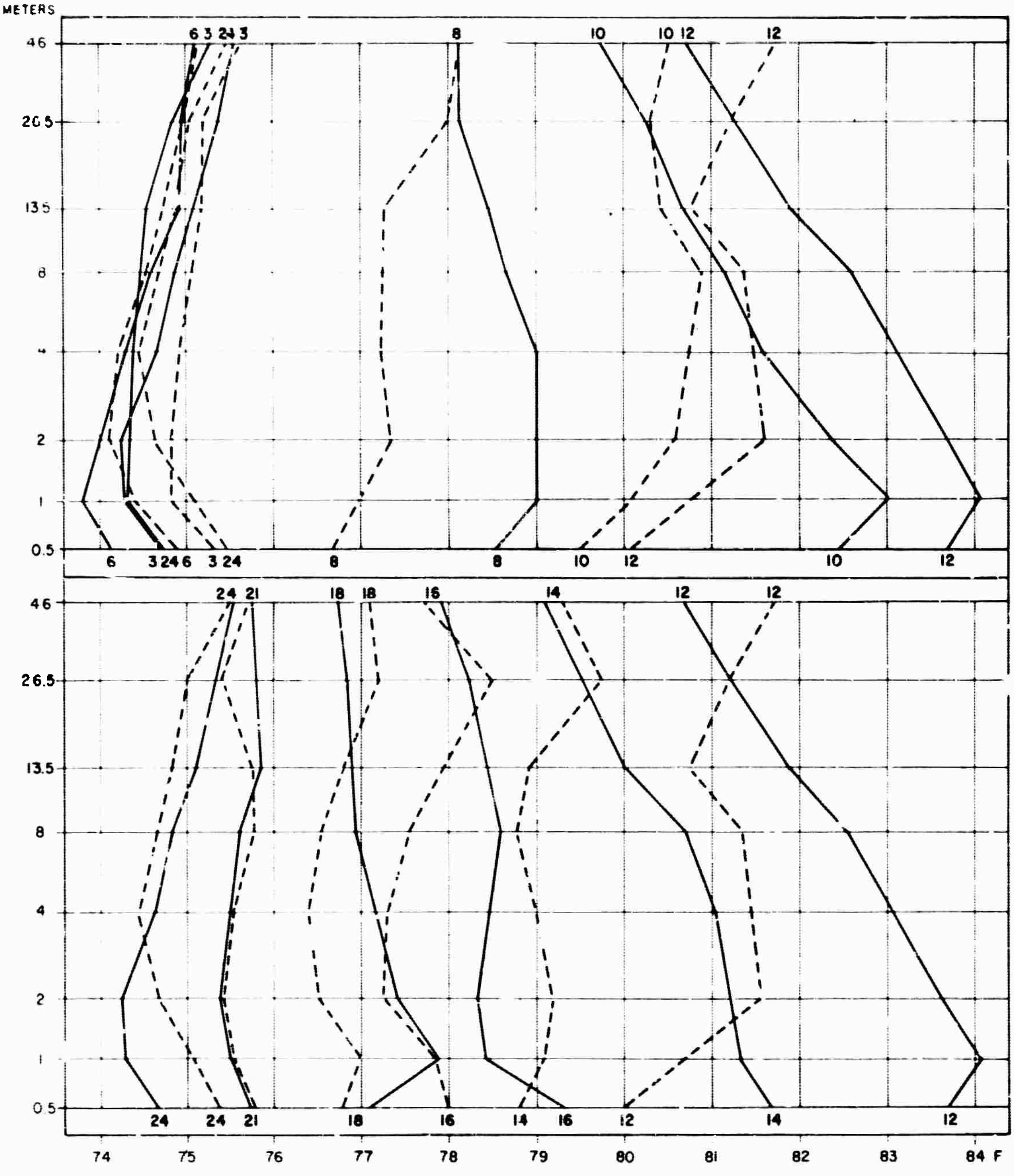


FIGURE IV-10. VERTICAL TEMPERATURE PROFILES, MEAN OF 10 DAYS WITH RAIN AT NOON

SOLID LINES - CHIVA CHIVA DASHED LINES - ALBROOK FOREST NUMERALS - HOURS LOCAL TIME

FIGURE IV-10. VERTICAL TEMPERATURE PROFILES, MEAN OF 10 DAYS WITH RAIN AT NOON

but not over, the observation sites. On several of the days when no rain fell at the sites, the observer heard thunder, in one case even overhead. (This was on 23 September.) Only a few drops fell at Chiva Chiva and none at Albrook, but at both stations the temperature maximum at all levels occurred at the time when the first thunder was heard, or earlier. The temperature drop after the maximum was considerable, e.g., at the 2-m level Chiva Chiva showed 90.6 F at 1100 hours, 83.1 F at 1200 and 80.6 F at 1300. The changes at the other levels were of the same order of magnitude.

As expected the highest temperatures occurred near the ground at Chiva Chiva and near the treetops at Albrook. At both stations the lowest temperatures (near 72 F) were recorded at low levels and the highest, 83 F, just above the trees in Albrook, and 86 F in Chiva Chiva at the 50-cm level, the lowest for which observations are available.

The fact that the lowest temperature at Chiva Chiva did not occur at the lowest level but at two meters above ground was unexpected. However, this may be explained through the assumption that the nighttime cooling of the air is not only accomplished through contact with the cool ground but also through direct radiational loss of heat into space. This interpretation is supported by measurements made by Florida State University over the open Atlantic Ocean, as reported by Garstang(2). It was found that the air temperature over the open water responds immediately to sunrise and sunset while the water temperature lags considerably. Thus, the air temperature before sunrise was lower than the water temperature but passed quickly above the latter after sunrise. The occurrence of ample dew at the Data Base observation sites provides some analogy with the conditions investigated by Florida State (although dew does not display the sizeable convection that is typical for open water bodies).

Table IV-3 compares some mean temperatures obtained in Chiva Chiva on days without rain, with mean temperatures obtained aboard the research vessel "Crawford" in August/September 1957 in the Atlantic off the Guiana coast at a latitude approximating that of the Canal Zone.

TABLE IV-3. MEAN TEMPERATURES AT SELECTED HOURS IN THE CANAL ZONE AND OVER THE OPEN SEA

	Chiva Chiva		Open Sea		
Hour	0500	1000	0500	1000	
2 meters	71.8	84.2	80.5	84.5	6 meters
1/2 meter	72.4	83.3	83.4	84.1	water
Difference	-0.6	+0.9	-2.9	+0.4	

The solid lines of Figure IV-10 and the portions of Figure IV-8 applicable to Chiva Chiva show that the described effect lasts until noon on days with rain, and until 1000 hours on days without rain. Although the magnitude of the described effect is small, it may assume considerable importance because the sign of the vertical temperature gradient is opposite to the "normal" during substantial parts of the day.

The publications of Garstang[2] and Cachan[4] are the only ones known to present temperature measurements from very low levels for average days. Instead, most writers have concentrated on selected clear days even in regions where such days occur with much lower frequency than cloudy days. From measurements taken on such clear days it has been concluded that the temperature of the very lowest layers of the atmosphere decreases substantially with height during hours of incoming radiation (day), and increases during the night when outgoing radiation prevails. During September 1966 this supposition has been contradicted at our stations:

64% of the time at Chiva Chiva on days without rain,
75% of the time in Albrook Forest on days without rain,
84% of the time at Chiva Chiva on days with rain, and
92% of the time in Albrook Forest on days with rain

It can be expected that within the short dry season the conditions would correspond better to the type of regime that is usually described. This subject will be taken up again below.

Unfortunately no reliable temperature measurements are available at heights below 50 cm or at the ground surface. Measurements of the soil surface temperature are extremely difficult. It appears that such measurements will be more reliable in future work of the Data Base Project.

Table IV-4 presents information on average temperature extremes observed at different levels at both sites. In this computation each day of September 1966 has been considered; means of this type are not sufficiently representative when they are based on only ten days or less. (The reader should consider that the extremes derived from a smoothed mean function, such as in Figure IV-14, are not the same as mean extremes taken from the daily curves before averaging.)

The hours at which the extremes were measured varied through any daytime hour for the maximum, and any night hour for the minimum. Frequently the temperature remained nearly constant for several hours. Usually the rise (or decline) to the maximum (or minimum) was rather gradual, while the drop (or rise) after the maximum (or minimum) was abrupt. The period of high temperatures was generally abruptly terminated by rain, either at the station or nearby; and the period of low temperature was usually abruptly terminated by the rising sun, even when the sun was hidden by clouds.

Little difference exists between the mean temperature minima at the open site and forest. At no level is the deviation from the common mean,

TABLE IV-4. MEAN TEMPERATURE EXTREMES DURING SEPTEMBER 1966

	Maxima		Minima	
	Albrook	Chiva Chiva	Albrook	Chiva Chiva
46 meters	84.8	84.7	74.1	73.4
26.5	86.1	85.6	73.1	73.3
13.5	84.2	85.8	73.3	73.5
8	83.7	--	73.1	--
4	83.4	87.0	73.1	72.5
2	83.2	87.6	73.2	72.5
1	82.8	87.8	73.7	72.7
0.50	81.7	87.4	73.8	73.1

73.2, greater than 0.9 F.

Except for the lowest layer the temperature maxima at Chiva Chiva decreased with height. The absolute maximum was recorded at 1 meter above ground (94.2 F). In contrast to this, the maximum temperatures in the forest show a slight increase from the ground up to the crowns of the trees. There it rises considerably and has its highest value at 26.5 meters. Also the absolute maximum (90.8 F) was recorded at that level. As expected the mean maximum temperature decreases above the treetop level. Since the mean minimum temperatures are almost equal at all levels, this variation of the maximum temperatures means that the temperature spread between minimum and maximum temperatures is greatest in Chiva Chiva at the 2-m level (15.2 F) from where it decreases upward and downward. At Albrook the maximum spread is measured at the upper side of the canopy (13.0 F). At either station the decrease of spread from the 1- to the 0.5-m level is surprisingly large.

It seems to be natural that at Chiva Chiva very high and very low temperatures occurred on the same days, namely on days with reduced cloudiness ("radiation days"). Surprisingly this happened also in the forest. At 8 meters, for example, the lowest temperature was 69.8 F and occurred on 2 September. The temperature maximum on the same day at this level was 86.4 F. Only two other days of that month had higher temperatures (86.8 F on both). This obvious reaction of inside-forest temperatures to sky conditions accords with the experience that the small variations of temperature traces occur at practically the same time at all levels. This shows that short-time irregularities of the temperature above the canopy are rapidly translated, though with reduced amplitudes, to lower layers.

<u>Temperature Variation with Time</u>. Figure IV-9 presents the temperature changes from one hour to the next for the seven days without rain at either station and for the ten days with rain at both sites. The general situation is, of course, of temperatures rising from sunrise to noon, and falling during the remainder of the day. The deviations from this simple pattern are discussed in the following paragraphs.

<u>Days without Rain at either Station</u>. Typically, the open site shows the greatest temperature change near the ground, the forest station near the treetops. As discussed before, the open station does not exhibit the fastest temperature rise directly at the ground, but some meters above. At both stations the changes lag with height. The strongest rise occurs first in the higher layers and spreads towards the ground; this is also true for the temperature drop in the forest. In the open site the most pronounced fall is first observed at the lowest layer and spreads upward. In each case the lag is from one-half to one hour. There are indications that the lagging is reversed at the very highest layer. This effect, however, is not strong enough to be ascertained.

<u>Days with Rain at Noon at Both Stations</u>. The cooling produced by the rain becomes more obvious in Figure IV-9 than in Figure IV-8 and renders the graph for Chiva Chiva difficult to interpret. Nevertheless, it can

be seen that the soil tends to have a smoothing effect: neither the temperature drop in the early afternoon nor the rise a few hours before are as strong at the ground as they are a few meters above it. In contrast to days without rain, the temperature drop in the afternoon occurs in two steps rather than gradually, the first of which is initiated by the rain, the second by the approaching night.

Irregularity of Temperature Drop at Night. Newton's law of cooling requires the undisturbed temperature drop to follow an exponential curve. As a matter of fact, this has frequently been found to be the case in dry conditions without, or with only a few, clouds. Conditions are not that simple in the Canal Zone. The portions of Figure IV-9 referring to nighttime conditions show deviations from Newton's law by the inclusion of periods of warming and periods of diminished rate of cooling, or by having the strongest cooling at the very end of the cooling period. Comparison of the four graphs suggests that these deviations always occur at the same times. Encouraged by this preliminary finding, and in order to work on a broader statistical basis, the average of all 30 days was considered.

Figure IV-11 shows the average hourly cooling rate of the 4-meter level for both sites, taken for all 30 days, as well as the theoretical rate that corresponds to Newton's law. It is obvious that both the forest site and the open site exhibit slower cooling rates at the same times, from 2100 to 2200 hours and from 0200 to 0300 hours, than would have been expected. Between these periods the cooling rate at both locations is more than Newton's law suggests(October and November show a very similar pattern). The very lowest layer (not presented here) shows the same effect at both stations approximately one hour later than does the 4-meter level.

Attempts to correlate the irregularities of the cooling rate with the periods of low or total cloudiness failed. While the total cloudiness decreases at an almost constant rate until 0400 hours, the low cloudiness remains almost constant with slight variations that do not coincide with the variations of the cooling rate. No attempts have been made to correlate the cooling rate with the moisture of the air, dew formation, or wind.

Temperature Variation with Height. The vertical variation of air temperatures is of great importance for propagation of sound and radio waves, as well as for the transport of gases and particulate matter such as liquid water, bacteria, spores, dust, etc. In macrometeorology the actual temperature variation with height is compared with the adiabatic lapse rate, which is 10 C per kilometer or 0.018 F per meter. Since we deal with heights of not more than 46 meters, the adiabatic temperature difference cannot be more than 0.8 F. Because we concentrate on narrower layers the adiabatic lapse rate may be disregarded. With this simplification temperature decreases with height will denote super-adiabatic conditions, and temperature increases (inversions), sub-adiabatic conditions.

From the temperature distribution shown by Figure IV-8 discussed above, considerable divergence may be expected between the current

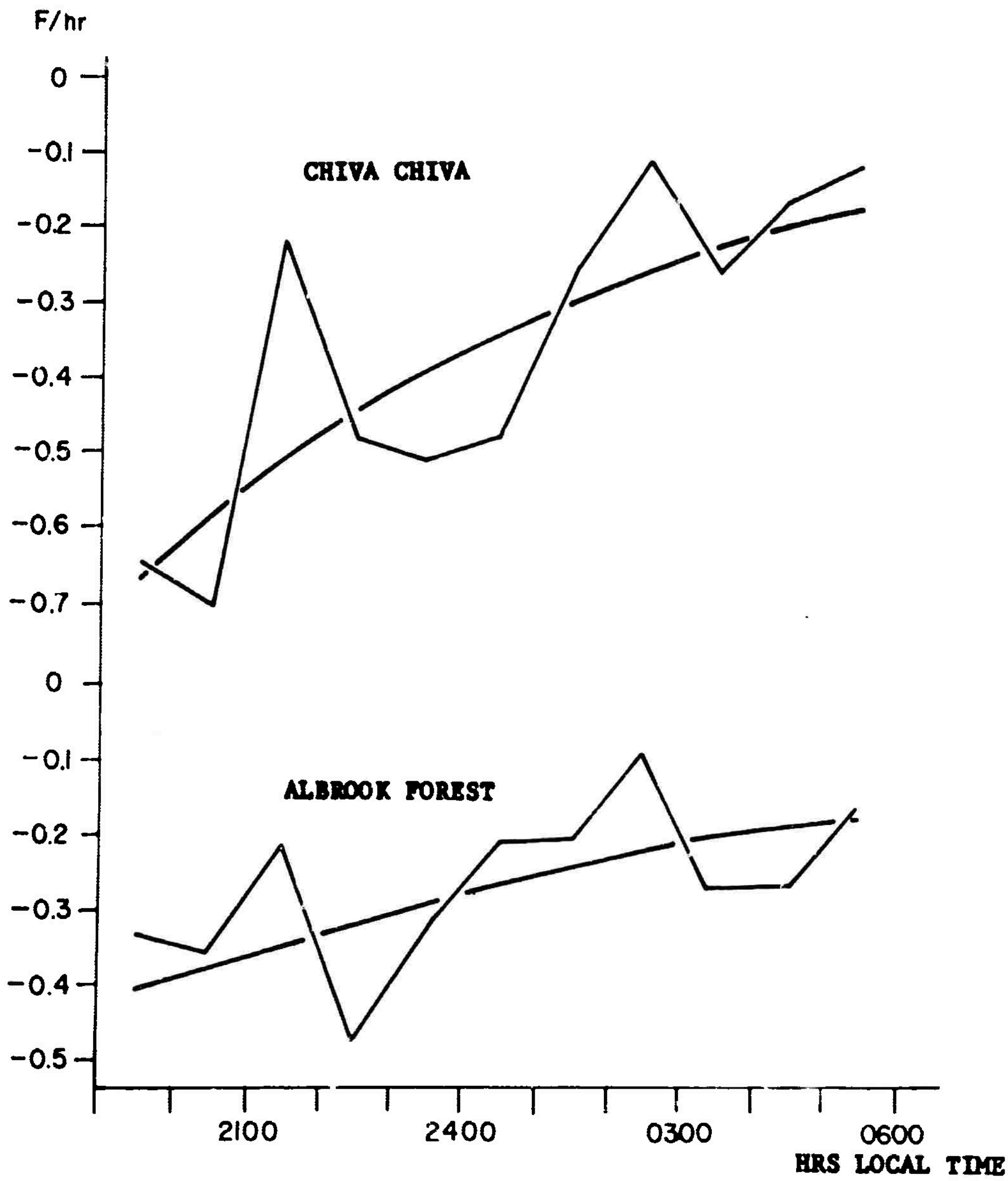


FIGURE IV-11. COOLING RATES AT 4 M ABOVE GROUND DURING SEPTEMBER 1966

Rugged curves - actual data
Smooth curves - Newton's law of cooling

measurements and the "textbook scheme". Figure IV-12 shows, in its upper part, vertical temperature variations during 24 hours as they can be derived from measurements made at the Laboratory of Climatology in Seabrook, N. J. and quoted in Geiger's textbook(3). They display temperature decreases with height during most of the daytime, and increases (inversions) during the night.

The lower part of Figure IV-12 presents the corresponding data of Chiva Chiva for "days with rain" and "days without rain" combined (almost the same figure results from using all 30 days without smoothing). In the uppermost layer, 4-8 meters, both parts of Figure IV-12 coincide reasonably well. However, in the lowest layers they are substantially different. Hence, the phenomena influenced by temperature stratification, such as propagation of electro-magnetic waves, and transport of atmospheric contaminants, may show diurnal variations that are different from those that can be derived from "idealized" data published so far. Data for "undisturbed" days, as those published for Seabrook, can hardly be applied to the Canal Zone, because undisturbed days are rare in the short dry season and nonexistent during the nine-month rainy season.

The dislocation of temperature extremes at the open site has the strange consequence that the lapse rate of the lower layer has a double diurnal wave. Table IV-5 (which partly overlaps with Table IV-3) shows the temperatures at the 50-cm and 4-m levels of Chiva Chiva at the hours of greatest elongation. Other layers, sites, or weather exhibit this effect only in a lesser degree or not at all.

TABLE IV-5. MEAN TEMPERATURES (F) AT CHIVA CHIVA ON SEVEN DAYS WITHOUT RAIN AT EITHER SITE

Hour	0000	0800	1300	1900	2000
4 meters	73.2	79.0	84.6	76.8	76.0
50 cm	73.7	77.3	86.2	76.5	75.7
Difference	-0.5	+1.7	-1.6	+0.3	+0.3

In a study of a forest environment near Abidjan, Ivory Coast, Cachan(4) found such a double wave between the layers over and below the canopy, ie., between the 46- and 11-m levels. In this respect there is no similarity between Cachan's data and those of the Canal Zone. His well expressed maxima of vertical temperature differences were found for the same hours where the Albrook data have indistinct minima. Cachan's maxima rise 8 F over the minima, the maxima in the Canal Zone only 1 F. At the present stage of investigation no explanation for this discrepancy can be given. (It is not evident from Cachan's publications(4, 5, 6) whether this

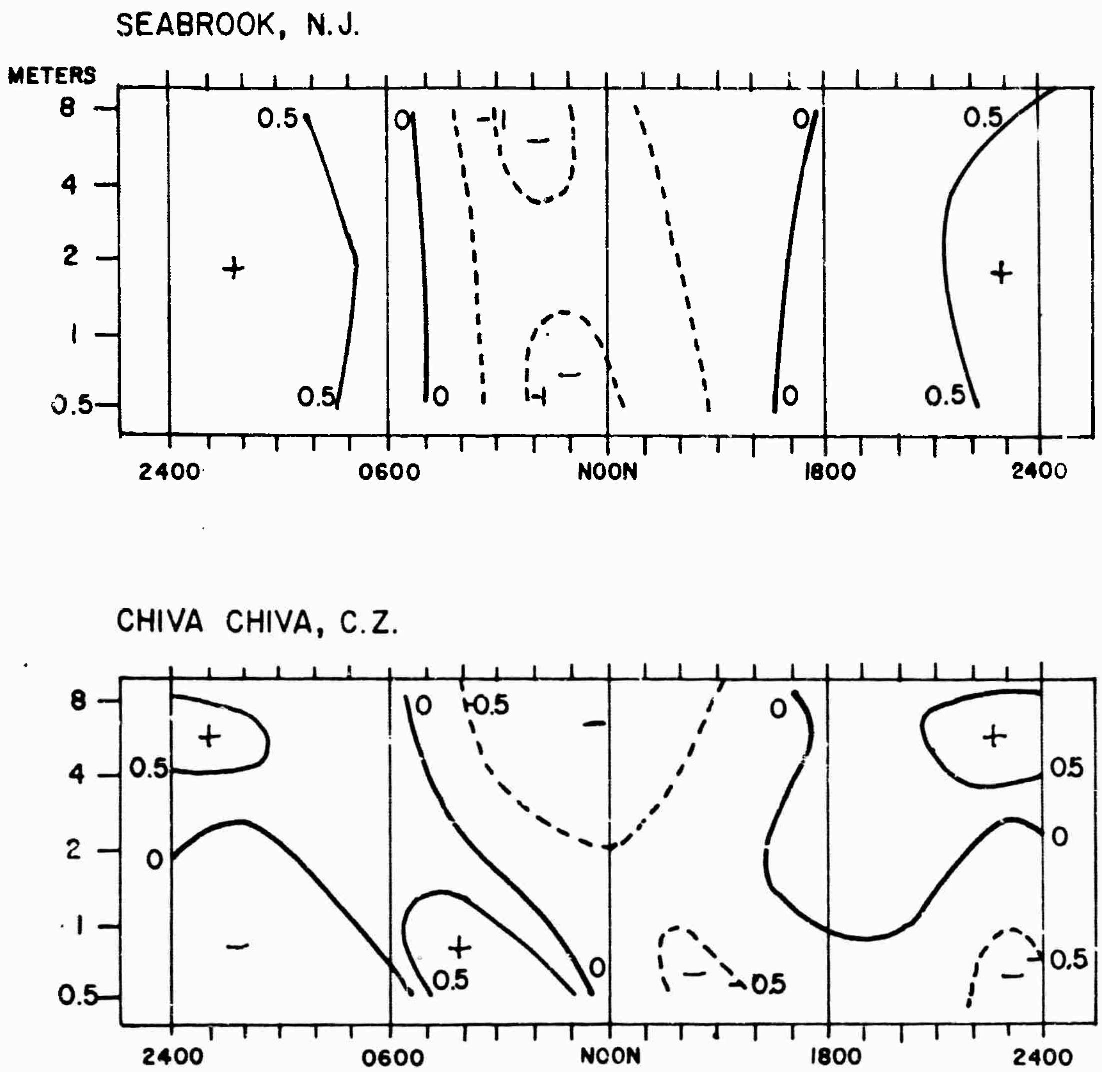


FIGURE IV-12. VERTICAL TEMPERATURE DIFFERENCES (F) BETWEEN THE LEVELS INDICATED AT THE LEFT MARGIN

Solid lines = increase of temperature with height = inversion

phenomenon occurs regularly or only under special conditions.)

Figure IV-10, derived from the lower part of Figure IV-8, compares the vertical temperature stratification of both Cane Zone sites for the same days and the same hours. At the time of the lowest temperature, 0600 hours, both stations show the same type of temperature stratification near the ground, though expressed somewhat better at the open site than in the forest. Before 0800 hours the temperature has risen much more rapidly in the lower layers of the open site than in the forest, but at 46 meters the temperatures at both sites are identical. At both stations the rate of temperature rise at the lowest level is less than at some meters above, which produces a shallow but well marked inversion. The forested site shows in addition a second inversion through and above the treetops. Both inversions are still present at 1200 hours, and, in the forest, until sunset. This is true in spite of the fact that the temperatures are decreasing as a consequence of the rain.

At 1400, and, not quite as well expressed, at 1600 hours, the temperatures for Chiva Chiva finally show a vertical distribution which corresponds to what one might have expected: straight cooling from the ground to 46 meters.

Comparison of the curves for 1800, 2100, 0300, and 0600 hours at Chiva Chiva demonstrates how the middle layers cool off more rapidly than the lowest or the highest layers. In this way an inversion develops that does not begin at the ground as would be normal in a typical radiation regime.

The temperatures and their variations with time and height are generally less extreme than one could expect from measurements made at higher latitudes. Apparently the long night and the high moisture content of the air tend to equalize the radiative and convective processes. It is regrettable that Cachan's[4] data are not summarized in the form of averages for particular hours. It would be interesting to compare his data, obtained in a typical monsoon climate in an old, dense forest with that of the current study, obtained at the downstream end of a trade wind climate in a relatively young forest.

Determination of Temperature at the Soil Surface*

Introduction and Discussion of Problem

Soil surface temperatures are important for many reasons. They affect everything in contact with the ground as, for example, vehicle tires, personnel on foot, animals, and also the air with suspended microorganisms. Seedlings pass through the soil surface; fruits, seeds, and spores fall onto the ground. Little is known of the manner in which the temperature of the soil surface furthers or impedes life and the propagation of life, mainly because the temperatures are not well known. In addition to the direct effects produced by contact with the soil, there are remote effects through radiation from it.

For centuries one principle has been used for measurement of temperatures. That is to equalize the temperature of a thermometer with that of the body whose temperature is required, after which the former is read. The difficulty of achieving the necessary equality of temperatures is well known. and requires special, but not always adequate, provisions for the purpose. For example, when measuring the temperature of air, the thermometer must be ventilated, yet simultaneously protected against radiation, even against that of the observer's own body.

The sensing part of a thermometer will adopt the temperature of a body when it is completely submerged in it for enough time. It is not difficult to measure the temperature within a body of soil. Because of the stable thermal properties of soil, its inner temperature will not change rapidly, and even if the thermometer is not in complete contact with the soil the sensor will adopt the soil temperature with a high degree of accuracy.

The situation is, however, completely different at the soil surface. There the temperature is a compromise between the energy of incoming and outgoing radiation, the heat capacity of the soil and of the overlying air, the heat conduction (molecular as well as turbulent) of the air, and the heat conduction of the soil. The temperature can further be substantially modified through evaporation, dew formation, or precipitation.

The complex thermal conditions at the surface juxtaposed to stable and inert conditions within the soil permit marked temperature differences between the surface and the interior of the soil. Until now it has very rarely been possible to measure them with the desirable accuracy. One may conclude, from several sets of observations from various sources, that temperature changes of approximately 6 C in the uppermost centimeter of soil are not uncommon. This gradient diminishes rapidly with depth, and the same difference, 6 C, has been found as a maximum between 5 and 20 cm depth.

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* This section has been prepared by Dr. Wilfried H. Portig, Research Meteorologist.

Method and Principles of Instrumentation

It is clear that, when the temperature changes on the order of magnitude of 0.6 C within one millimeter, the sensor of a thermometer must be extremely thin. Furthermore it must respond to all types of conduction and radiation in exactly the same way as the soil. It is doubtful that such a thermometer exists. Since the problem of measuring the temperature of the surface of the soil cannot be solved with traditional direct means, indirect measurements seem to be more promising. Hoffmann wrote in the appendix of Geiger's book "Possibly the measurements of the soil surface temperature will soon be basically improved through utilizing the radiation emitted from the soil. Engineers already measure surface temperatures by means of this principle".

An infrared thermometer is an instrument for sensing certain radiation emitted from the surface of any body, and experiments (described below) seem to indicate that it will provide the means of measuring the soil surface temperature. The Research Division of the Tropic Test Center possesses two such instruments*, the operating principles of which are discussed in the following.

The surface of any body emits electromagnetic radiation over a wide spectrum. The amount of emitted energy depends on the surface temperature to the fourth power and on the emissivity of the body. The spectral spread depends on the temperature and on the emissivity which may change with temperature and with wave length. The conditions in the receiver are correspondingly complicated. Considering the multiple feedback of the temperature, one cannot say, a priori, how the received energy may be interpreted in terms of temperature.

Basically the instrument is entered only by radiation in the infrared part of the spectrum, and this incoming radiation is internally compared with a radiation source of constant temperature within the instrument. The difference between the internal and external energy sources is indicated on a dial in degrees of temperature, though the actual and indicated temperatures are different, as shown below.

The fundamental question was the unknown and possibly varying emissivity of the soil. The radiative energy entering the instrument is represented by the equation: $E = e\,k\,T^4$, where e is the emissivity of the observed surface, T is temperature (aboslute), and k is a constant. By definition, e may vary between 0 and 1; a body with emissivity e = 1, is called black. It has been known that soils have emissivities close to unity, but just how close was not known. The manufacturer stated that e is between 0.9 and 1. This means that a soil sample of e = 0.9 and 300 abs. would give the same instrument reading as a sample of e = 1 and 292 abs. This error would have

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* Infrared Thermometer. IT-3E; manufactured by Barnes Engineering Co., Stamford, Conn.

been too large. It was shown through a series of calibrations with different kinds of soil that the error is actually much smaller, i.e., that the emissivity in the used wave lengths and at realistic temperatures differ very little. Details of the measurements are given below.

Another problem is the loss of energy between the emitting surface and the sensor. This is of no concern when the distance is short but must be considered when measurements over longer distances are planned.

The infrared instrument contains as stated above, a radiation source which serves as a base line for the incoming radiation. The mechanism of the instrument brings part of this radiation out of the instrument where it can have two effects. First, it may be reflected back into the instrument, which is not capable of distinguishing between the radiation it is supposed to measure and the additional reflected light. Second, the outgoing radiation may heat up the tested surface precisely at the place where the measurement is taken. The reflection effect can be almost completely eliminated by avoiding a perpendicular orientation of the instrument to the tested surface. This is not important as long as soil is measured, but in cases of high reflectivity, as typical for metals or water, the axis of the instrument must not be perpendicular to the tested surface. In testing the instrument on polished metal objects it was found that the temperature reading increased by as much as 20 C, or more, precisely as the 90° orientation was reached. The second effect, the heating of the tested surface by the instrument, may be considered as negligible in most cases, since the emitted energy is rather small so that no significant heating can occur, and also the radiation from the instrument must hit the surface for some time before it can accumulate to a measurable increment of temperature. However, in cases of stationary installations, e.g., for the permanent recording of a surface temperature, the heating effect must be checked to avoid modification of conditions under investigation.

Another effect that may reduce the usefulness of the infrared thermometer is the temperature of the instrument. The reference radiation inside the instrument is produced by heating a "black body" to a certain temperature at which it is maintained by a sensitive thermostat. This process, however, can work only as long as the instrument as a whole is cooler than the standard reference (approximately 60 C). Since the temperature of a body exposed to the tropical sun may become as high or higher than the reference temperature, the infrared instrument must be appropriately shielded when used in the open.

Two disadvantages of the instrument may be of importance in some kinds of application. First, the instrument needs a power source. Our instrument works only with 110 volts AC. A new type just announced, operates with batteries. It is however, very difficult to use dry batteries in a humid tropical environment satisfactorily, where high moisture and delayed supply routes introduce problems. Second, the sensor and the indicator portions of the instrument are connected by a 20-conductor cable, which offers considerable mechanical resistance to movement. Consequently two

persons are required to handle the device, one for aiming and one for reading. This difficulty is overcome in a stationary installation, as for the Data Base project, where routine measurements of the soil surface temperature are made concomitant with the other measurements made at fixed intervals and locations.

Calibration Measurements

Calibration of instruments is accomplished through comparison of the reaction to the same measureable characteristics of two instruments, one being investigated and the other known to be accurate. In this case the indication of the infrared thermometer must be compared with the actual temperature of the soil surface. The problem is to know the latter. The uppermost layer of the soil is known to change its temperature rapidly in response to varying conditions. Therefore it was necessary to maintain the soil samples under constant thermal conditions long enough for the internal and external temperatures to equalize. When this was accomplished, the internal temperature (now equal to the surface temperature) could be readily determined with a common mercury-in-glass thermometer. Because the internal soil temperature changes very slowly, it was necessary to spread the calibration measurements over several weeks.

Such measurements were carried out with different soil samples typical for this part of Panama: natural bare soil, as found at the Chiva Chiva site; the same soil with short grass; the same with moisture removed and volume compressed; and red clay prepared in the same way. Surprisingly and encouragingly, the infrared thermometer reacted in the same way to all the samples. This meant that the emissivity of the samples was equal, within the limits of accuracy with which the instrument can be read. This is also true for different degrees of wetness of the soil.

Measurements were made at three temperatures: in a normal storeroom of 26-27 C and high relative humidity of the air, in a climatized storeroom of 39-41 C with dry air, and in an oven at 52-54 C. The readings under the first two conditions were simple and unambiguous. In the oven the instrument readings were frequently unstable, and sometimes unexplained large differences were observed between the oven and the soil temperatures.

Figure IV-13 shows all 28 calibration measurements. They can be approximated by a straight line (not shown in the figure) of the equation: $t = 1.262\,(s - 39.2) + 35.7$ with a rms error of $\pm$ 0.73 where t = temperature in C, and s = indication of the infrared thermometer. The deviations between the measurements and the straight line are not randomly distributed, but suggest a slight bending of the calibration curve. Trying a second degree approximation, the method of the least squares yields the parabola:

$$t = 46.1 + 14.52\sqrt{s - 7.2} \text{ with a rms error of } \pm 0.66$$

and distribution of the errors seems to be random. The line in Figure IV-13 is this parabola, by means of which each instrument reading can be converted into temperature.

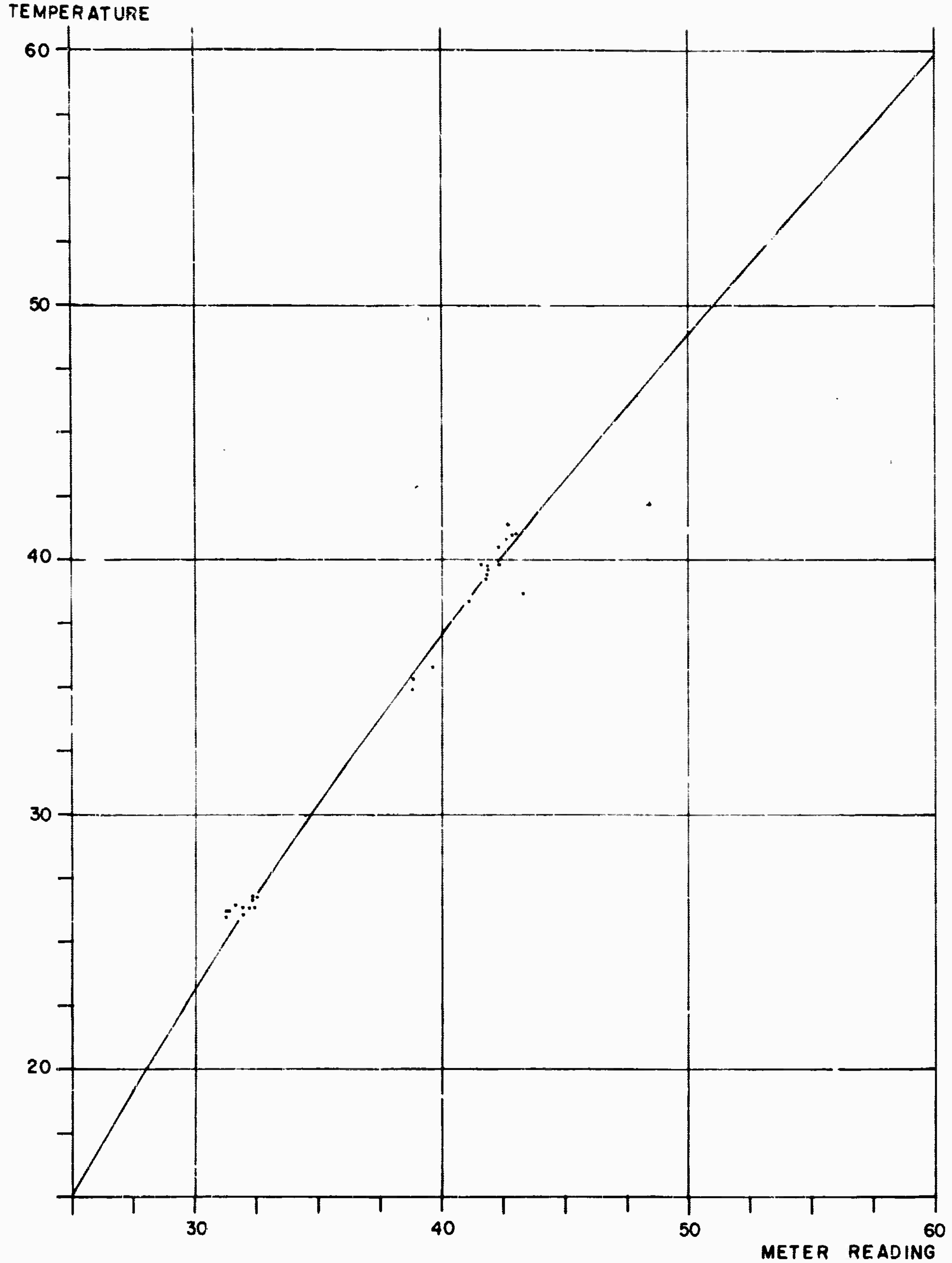

FIGURE IV-13. READING OF THE INFRARED THERMOMETER VS. TEMPERATURE (°C)

Summary

It has been shown that, with some restrictions, the Barnes infrared thermometer is an adequate instrument for measuring the soil surface temperature on a routine basis. The scale printed on the instrument must, however, be substantially modified in temperature ranges below 50 C. The different soils tested yielded equal temperature readings within the range of 25-54 C that was checked. Only dark soils (with and without grass), but no beach sand, were examined. Because of the encouraging results soil-surface temperatures are routinely measured with a Barnes infrared thermometer at the Chiva Chiva open site. Figure IV-2 shows views of the sensor and the indicator, respectively, together with the calibrated instrument which is being used as a check on the other. The indications of the "identical" instruments are substantially different (10 F) in lower temperature ranges; the difference is time-constant and reproducible. Further investigations are planned on the possibility of using the second instrument on the upper part of the Albrook tower to measure the temperature of the upper side of the forest canopy.

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PART V. SOILS AND HYDROLOGY*

Introduction

The soils and hydrology task of the Data Base Project encompasses four integrated data-gathering phases connected with studies of soil trafficability: (1) soil strength measurements, (2) soil sample measurements, (3) soil temperature and moisture measurements, and (4) ground water level measurements. Data are gathered at the Albrook Forest and Chiva Chiva main sites and at the satellite sites located at Fort Kobbe, Fort Sherman, and near the Albrook Forest site. Table V-1 summarizes the types of data collected and their scheduling at the various sites.

The data presented in this section constitute a continuation and an expansion of those reported in the previous Semiannual Report[1] detailed information on the three satellite sites is presented for the first time.

The one-time determination of bulk density and water tension samples was accomplished during this reporting period. Detailed descriptions of the soil profile for the two main and three satellite sites were prepared, and bulk samples for physical and chemical analysis were collected from each genetic horizon as well as from each three-inch increment layer, down to 18 inches.

Data Collection

Procedures and operational techniques outlined in the previous report have been followed in collecting the currently described information. The soil strength data, as measured by cone index and remolding index, were collected with the 0.5 and 0.2-square-inch cone penetrometers and remolding equipment developed by the US Army Engineer Waterways Experiment Station (WES). When soil conditions permitted, soil moisture and density samples were obtained with the trafficability sampler. Otherwise, an Oakfield punch or soil auger was used to obtain moisture samples only. The San Dimas sampler was employed for securing soil cores for bulk density and water tension determinations at 0 and 0.06 atmospheres. Tension determinations at 0.06 atmospheres were performed with the tension table developed by Leamer and Shaw[7] using double blotters as the porous medium and subjecting the samples to a constant tension of 60 cm of water for a 24-hour period after being thoroughly saturated for 36 hours. Other tension determinations were performed with the pressure membrane apparatus.

Bulk samples, to be used for physical and chemical analyses were collected from pits approximately one meter long, one-half meter wide, and one and one-half meters deep. The pits were dug to permit detailed description

* This section was prepared by Mr. Ricardo Ah Chu, Soils Scientist.

TABLE V-1. SOIL DATA COLLECTION SCHEDULE

	Type of Data and Frequency								
	Strength		Soil Sampling			Soil Temperature & Moisture		Groundwater Level	
Sites	Cone Index	Remolding Index	Moisture Content & Density	Bulk Density & Moisture Tension	Chemical & Physical Analysis*	Electrical Resistance	Telethermometers	Manual	Automatic
Albrook (Forest)	6/week 0-18"	3/week 6-12"	6/week 0-18"	One time 0-18"	One time 0-18" plus genetic layers	Hourly (two tiers) 4-100 cm. (8 depths)	None	4/day	None
Chiva Chiva (Open)	6/week 0-18"	3/week 6-12"	6/week 0-18"	One time 0-18"	One time 0-18" plus genetic layers	Hourly (one tier) 4-100 cm. (8 depths)	24/day (Sfc to 1 meter)	4/day	None
Satellite**	2/two weeks 0-18"	2/two weeks 6-12"	2/two weeks 0-12"	One time 0-18"	One time 0-18" plus genetic layers	None	None	None	Continuous

* **Physical Analyses**

Atterberg limits
Specific gravity
Water tension at 3 and 15 atmospheres
Grain size distribution

* **Chemical Analyses**

Nitrogen
Phosphorous
Potassium
Calcium
Minor Elements
Base exchange capacity
Organic matter content

** **Satellite Sites**

Albrook
Fort Kobbe
Fort Sherman

of the soil profile following procedures and techniques developed by the US Department of Agriculture.[8] Each genetic horizon was described on basis of the following characteristics: depth, color (Munsell numerical notation), texture, structure, consistency at different moisture levels, amount of roots, boundary and thickness of horizons, mottling conditions, and other characteristics deemed significant in the characterization of the horizon. After completion of the soil profile description a three or four pound bulk sample of each horizon was collected. These samples were processed and used in physical and chemical analyses. Detailed descriptions of soil profiles and summary tables of some of the physical characteristics determined in the laboratory are shown in Appendix A.

The fiberglass units and the soil moisture meter developed by Coleman and Hendrix[9] are used to obtain soil moisture information in-situ. A field calibration curve prepared for each unit is used to convert the readings obtained with the meter into approximately equivalent values of soil moisture content. Soil temperature is determined by the use of telethermometer probes at the Chiva Chiva site. Since additional probes were not available, the thermistors incorporated in the fiberglass units were utilized for this purpose at the Albrook site. The results obtained with these thermistors have not been satisfactory, however, and their use has been discontinued.

Fluctuation of the groundwater level is measured manually at the main environmental sites by inserting a graduated wooden rod in the cased well. Water-level measurements at the three satellite sites are automatically recorded.

Analysis of Data

Data obtained from each site are presented below, together with a partial graphic analysis showing some of the relationships observed between the various soil parameters. The collection of soil information from a plot at each of the main sites similar to the one depicted in Figure V-1 has been completed and is available for statistical analysis. The data reported here for the two main sites pertains to these plots. A new plot has since been established at each main site and collection of the same general type of information has continued. Moisture-strength-density summary tables are contained in Appendix A for each site; the analysis that follows is based on these data.

Soil Moisture Profiles

Moisture profiles from the Chiva Chiva and Albrook sites are presented in Figures V-2 and V-3 respectively. These profiles are plotted down to 18 inches at 3-inch increments and are shown by sampling date. Points on the profiles represent the average value derived from samples collected in pairs from three randomly chosen blocks (6 samples in all) within the soil plot at each site. Moisture contents were determined by weighing the

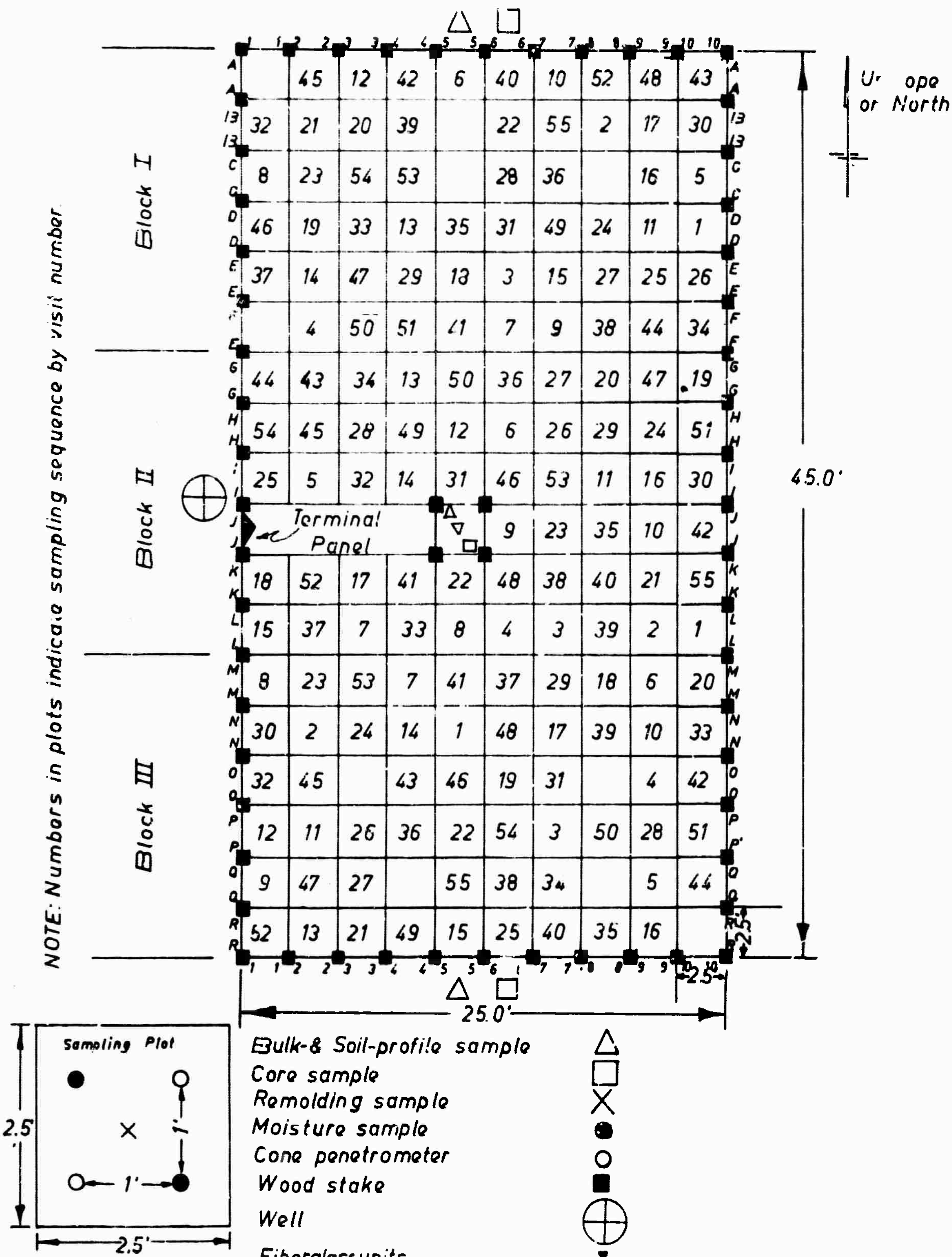

FIGURE V-1. LAYOUT OF SAMPLING PLOT AT THE CHIVA CHIVA AND ALBROOK FOREST SITES. (MODIFIED AFTER WES, 1962)

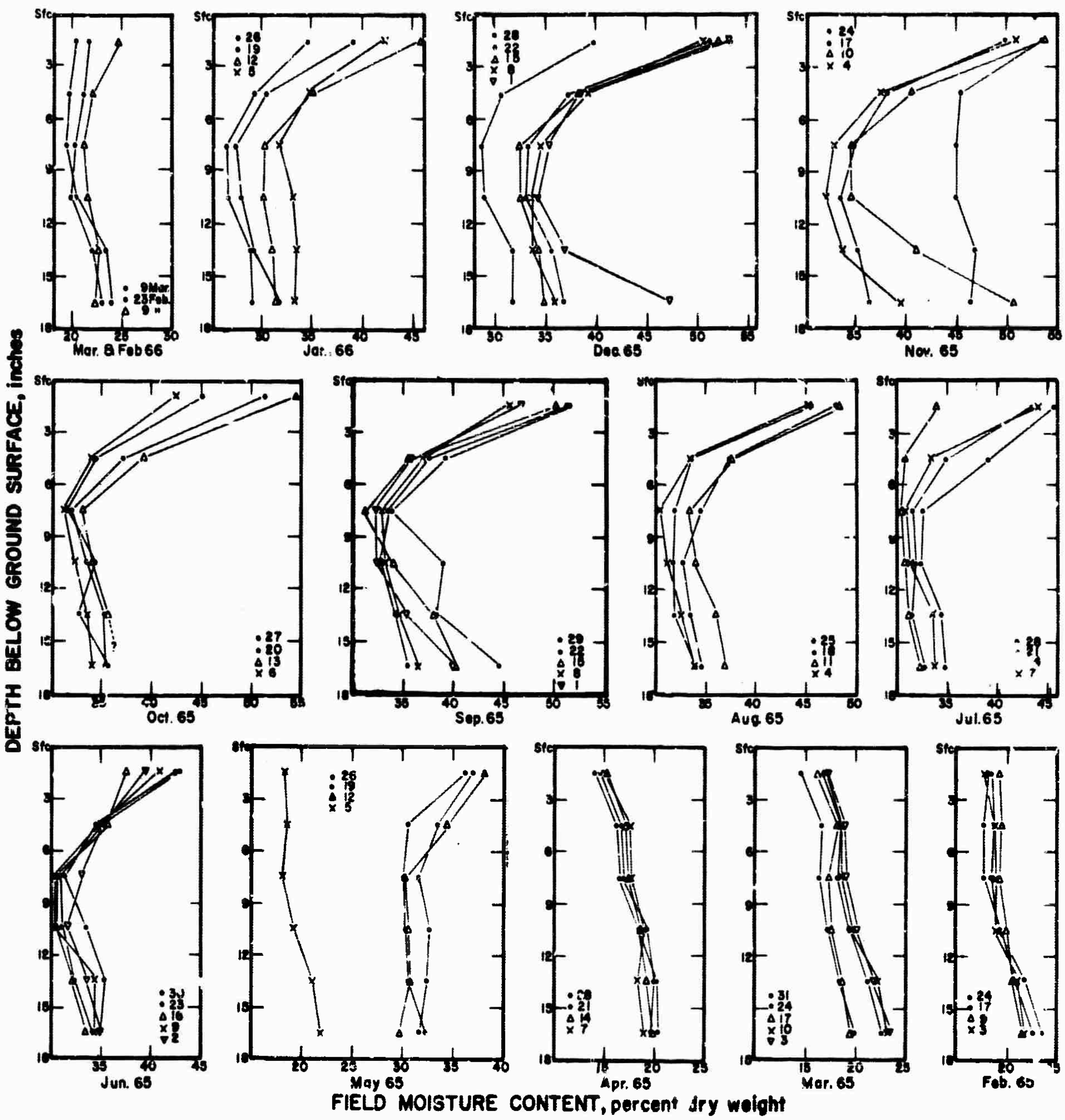

FIGURE V-2, MONTHLY VARIATION OF NATURAL FIELD MOISTURE CONTENT WITH DEPTH, CHIVA CHIVA SITE.

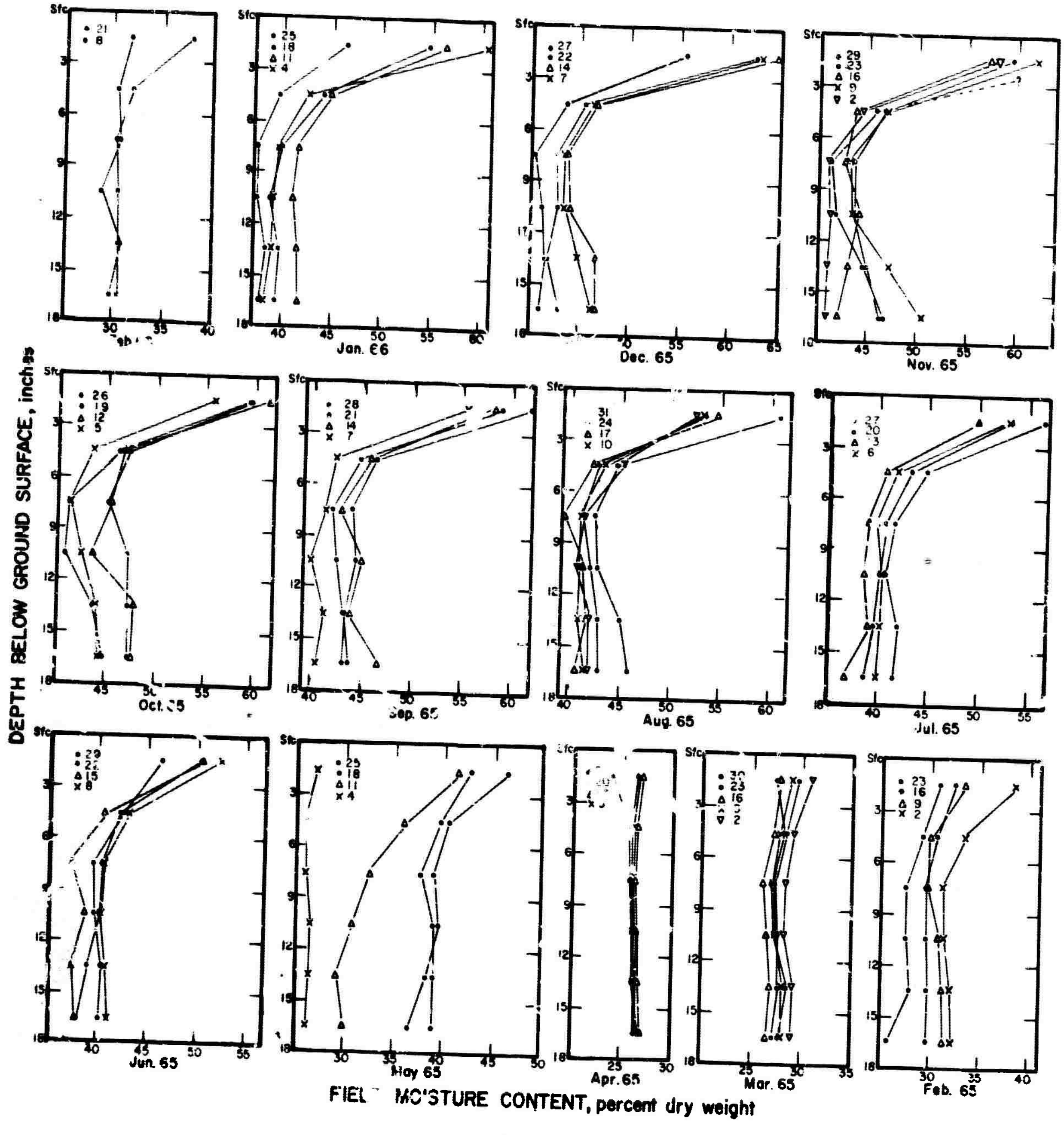

FIGURE V-3. MONTHLY VARIATION OF NATURAL FIELD MOISTURE CONTENT WITH DEPTH, ALBROOK FOREST SITE.

FIGURE V-3. MONTHLY VARIATION OF NATURAL FIELD MOISTURE CONTENT WITH DEPTH, ALBROOK FOREST SITE

samples before and after oven-drying. The results are expressed as a percentage based on the oven-dried weight of the soil.

A composite of all the moisture profiles has been grouped in Figure V-4 for overall comparison between the Chiva Chiva and Albrook sites. Moisture contents, as expected, are highest at both sites for the uppermost layers where the general physical conditions of the soils are more conducive to water retention during the wet season; bulk density, for example, averaged 0.87 and 0.99 grams per cc for the 3- and 6-inch depths respectively at lower depths it averaged as high as 1.17 grams per cc. Groundwater appears to be influential on the moisture regime of the soil between the 9- and 12-inch depths at the two main sites and increasingly so with advancement of the wet season as suggested by the sudden change in direction of the curves at this level. On the other hand, the groundwater level at both sites fluctuated most frequently between 10 and 20 inch depths during the wettest portion of the rainy season. (See Figures V-13 and V-14 of previous Semiannual Report(1).) The curves for the driest months (February, March, and April) show greater moisture differences between levels at Chiva Chiva than at Albrook, where moisture remained relatively constant from the 4.5-inch depth downward, although moisture content at all depths and at both sites decreased gradually as the dry season advanced. It is interesting to note that moisture at the surface, i.e.,the 0- to 3-inch layer, at the forest site, usually remained higher throughout the dry season, except for two instances when it dropped below that of the deeper layers. The low rate of moisture loss at the 0- to 3-inch layer where evaporative mechanisms exert greater influence, suggests, in part at least, that possibly the relative humidity within the soil about equalizes that of the outside environment in such a way that no significant gradient between the two exists. It is also possible that the rather thick mat of dry litter over the ground exerts a shielding effect which greatly reduced the evaporation of moisture from the soil surface. The litter study being conducted under the Data Base Project may eventually clarify this question.

Soil Strength Profiles

Figures V-5 and V-6 present soil strength profiles for the Chiva Chiva and Albrook Forest sites, respectively. The profiles are constructed from cone indices recorded by sampling date. The curves were derived from the average of six samples, obtained in pairs from three randomly selected blocks from the soil plot. Figure V-7 shows a composite of all the curves for both sites. In general, all the curves show a normal strength profile whereby soil strength augments with depth. Dry, wet, and intermediate season conditions readily show up on the composite graphs. However, data for the dry season from Chiva Chiva is not plotted because the firmness of the soil during the dry season impeded penetration of the instrument into the ground. Tables V-2 and V-3 for the Chiva Chiva and Albrook sites display distributions of cone indices by class interval, for each layer, for the period covered by the data. Table V-4 presents the range of cone indices at the two sites for each of the layers measured by seasons.

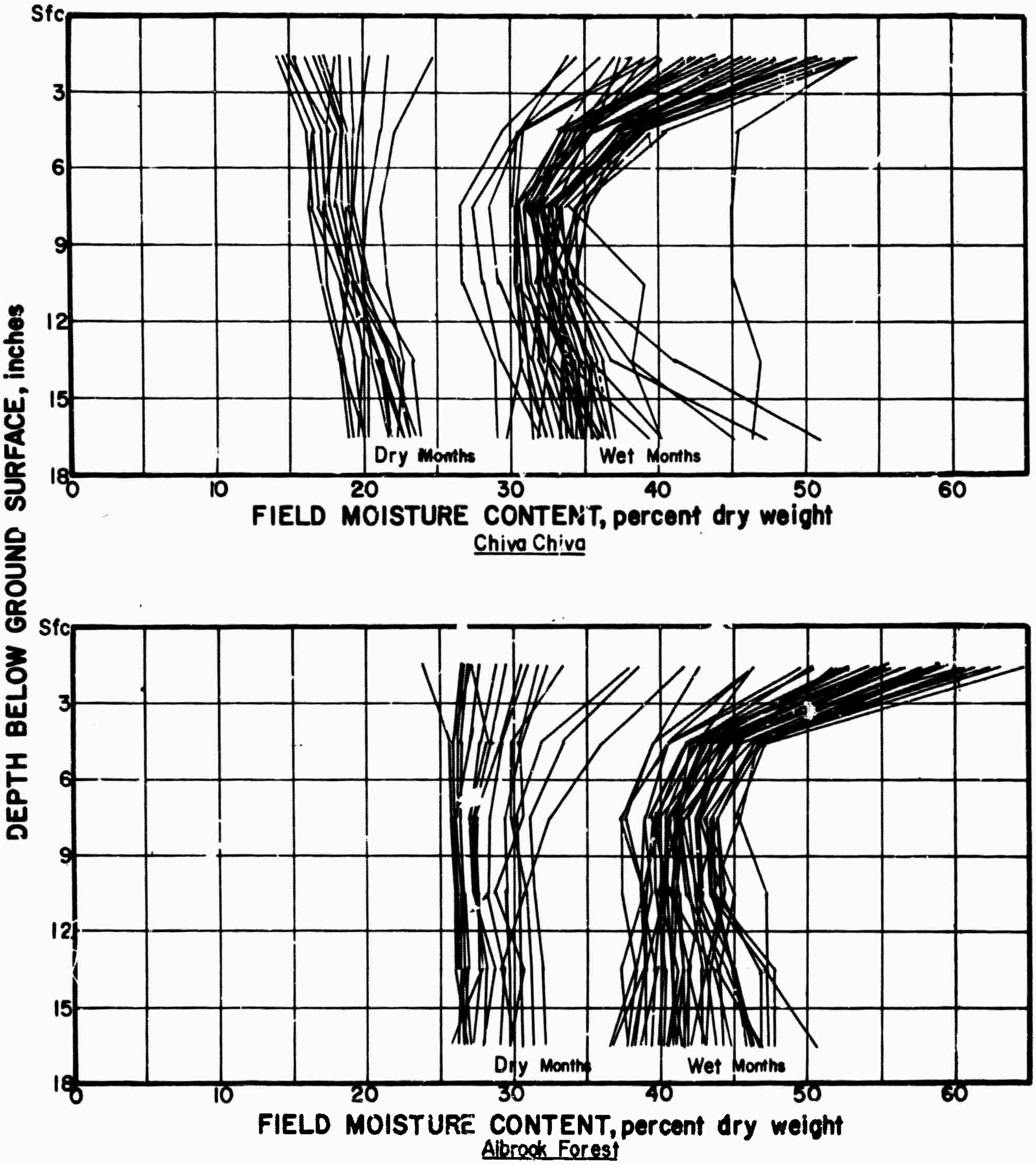

FIGURE V-4. COMPOSITE OF ALL SOIL MOISTURE PROFILES, CHIVA CHIVA AND ALBROOK FOREST SITES.

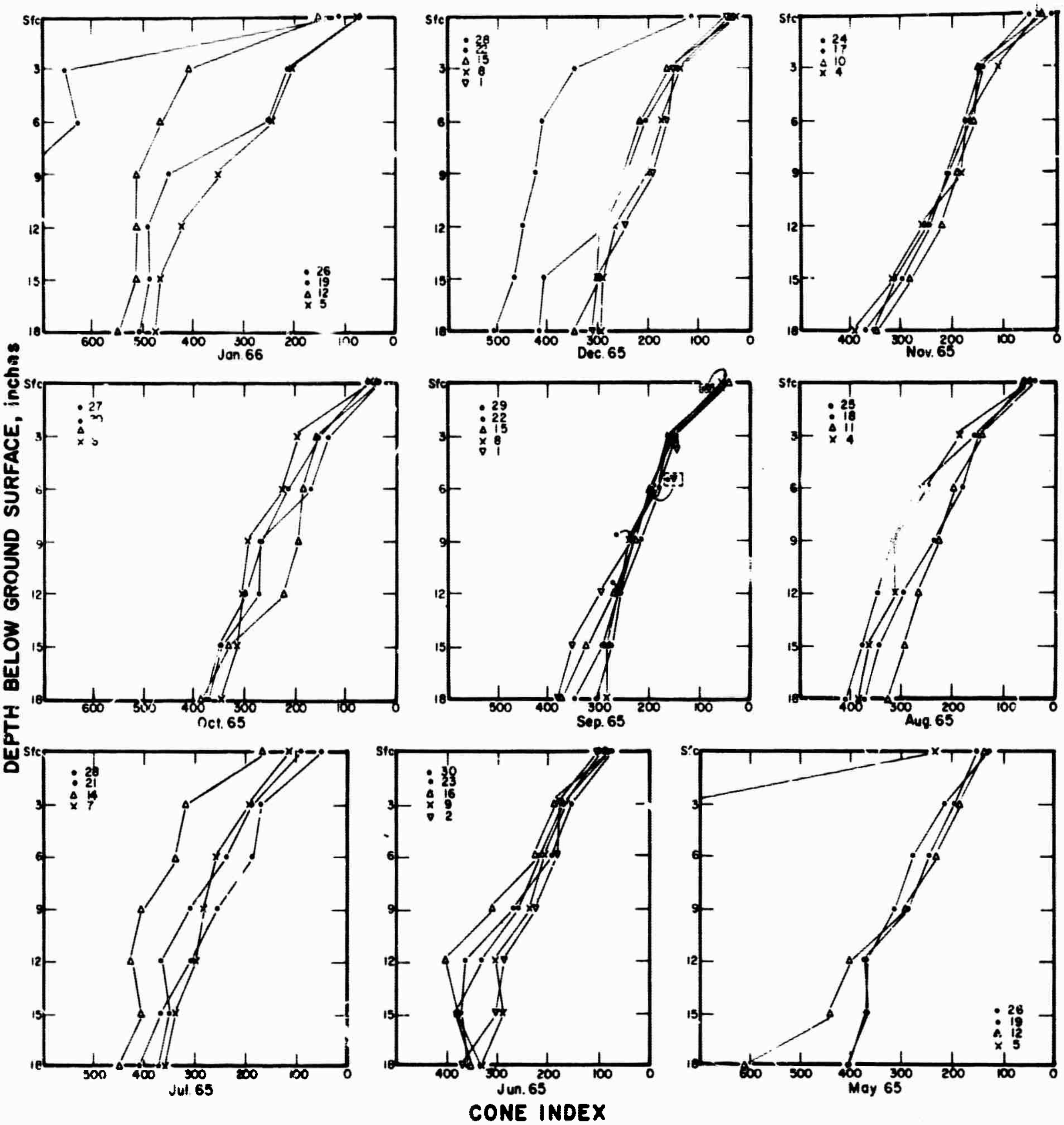

FIGURE V-5. MONTHLY VARIATION OF CONE INDEX WITH DEPTH, CHIVA CHIVA SITE

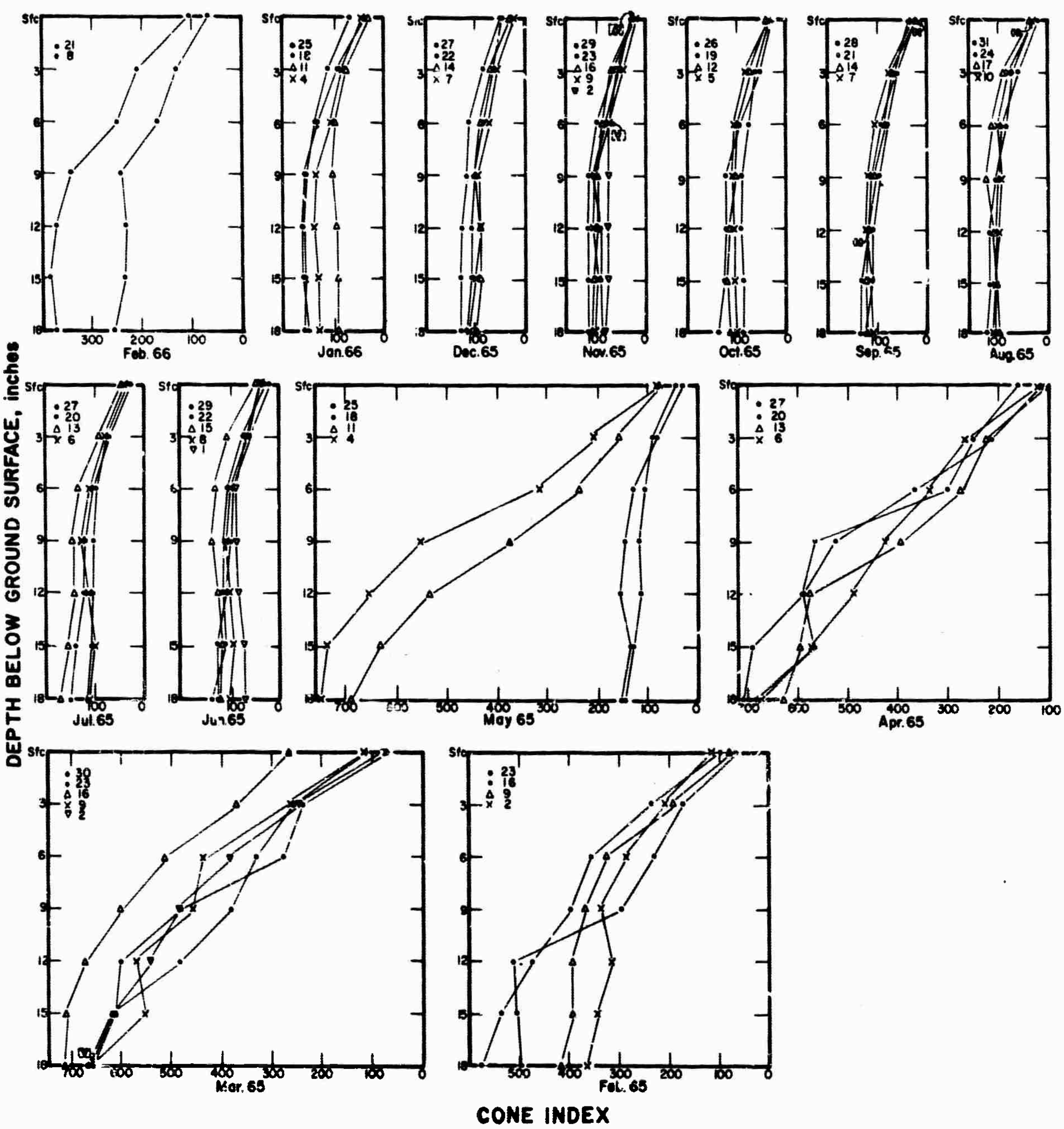

FIGURE V-6. MONTHLY VARIATION OF CONE INDEX WITH DEPTH, ALBROOK FOREST SITE.

FIGURE V-6. MONTHLY VARIATION OF CONE INDEX WITH DEPTH, ALBROOK FOREST SITE

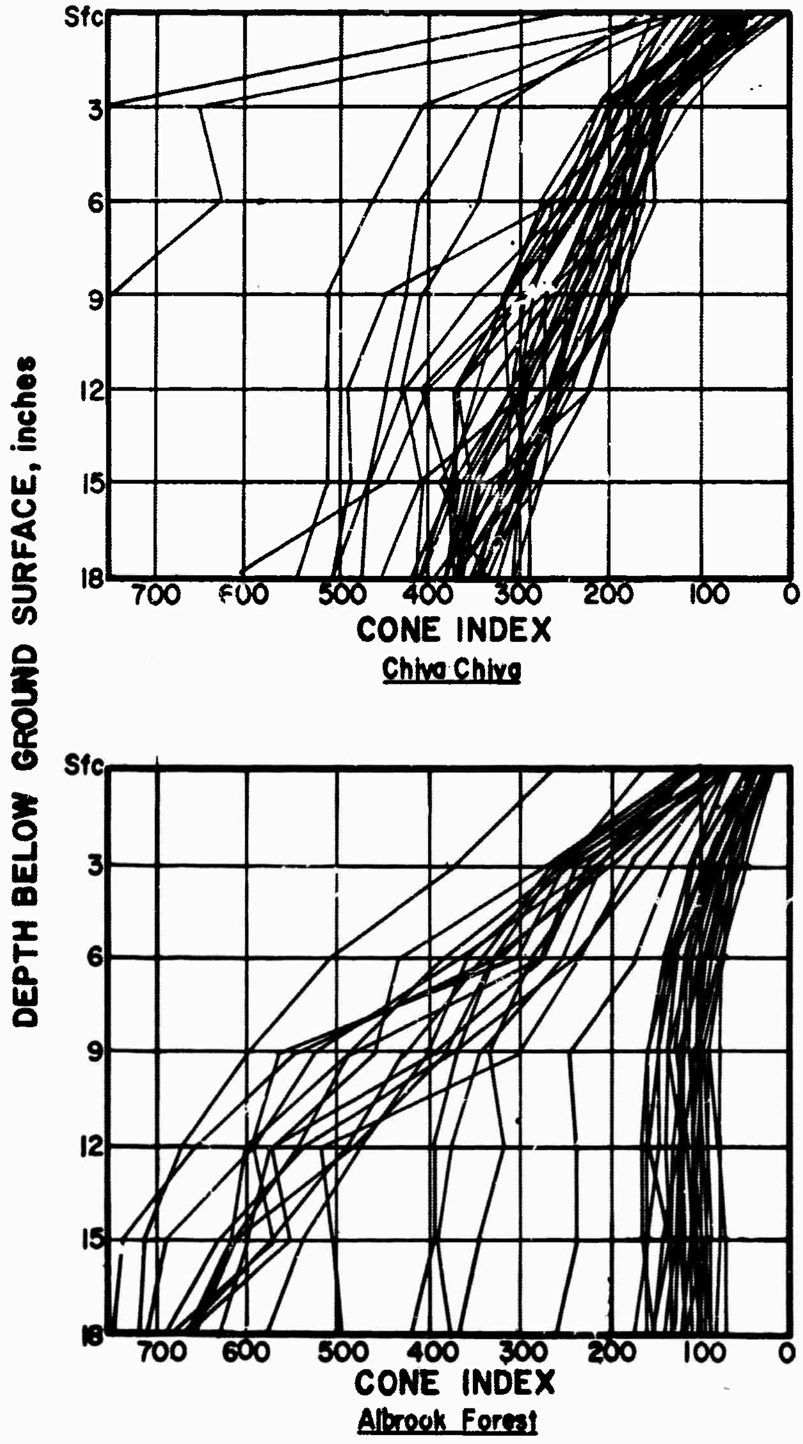

FIGURE V-7. COMPOSITE OF ALL CONE INDEX PROFILES, CHIVA CHIVA AND ALBROOK FOREST SITES.

TABLE V-2. DISTRIBUTION OF INDIVIDUAL FIELD CONE INDEX READINGS BY CLASS INTERVALS AT THE CHIVA CHIVA SITE*

Class Intervals in Cone Index Units	Sfc	3	6	9	12	15	18
0 - 24	10	-	-	-	-	-	-
25 - 49	69	-	-	-	-	-	-
50 - 74	67	-	1	-	-	-	1
75 - 99	33	4	-	-	-	-	-
100 - 124	22	9	1	2	1	-	-
125 - 149	16	48	13	-	1	-	-
150 - 174	14	70	37	14	-	-	-
175 - 199	14	34	46	26	8	4	1
200 - 224	14	27	36	36	22	12	4
225 - 249	10	13	33	28	25	13	10
250 - 274	16	2	21	32	27	23	18
275 - 299	8	3	12	20	23	14	10
300 - 324	3	-	3	11	18	20	15
325 - 349	-	1	3	8	12	19	12
350 - 374	1	1	1	8	24	26	26
375 - 399	-	-	4	5	13	20	22
400 - 424	-	4	4	9	18	21	34
425 - 449	-	4	4	5	3	18	13
450 - 474	4	2	-	12	12	9	18
475 - 499	-	-	1	2	5	8	11
500 - 524	1	-	-	1	6	6	5
525 - 549	1	2	2	2	1	3	3
550 - 574	8	1	1	1	1	3	7
575 - 599	1	1	3	-	2	-	2
600 - 624	1	-	2	-	-	2	4
625 - 649	2	1	-	1	-	-	2
650 - 674	1	2	-	-	-	2	1
675 - 699	1	2	-	-	1	-	2
700 - 724	-	-	-	-	-	-	-
725 - 749	-	-	-	2	-	-	-
750 +	13	99	102	105	107	107	106

* Individual field cone indices were used in making the distributions, contrasted to the use of average indices as shown on the strength profiles of the previous figures.

TABLE V-3. DISTRIBUTION OF INDIVIDUAL FIELD CONE INDEX READINGS BY CLASS INTERVALS AT THE ALBROOK FOREST SITE*

Class Intervals in Cone Index Units	Sfc	3	6	9	12	15	18
0 - 24	55	-	-	-	-	-	-
25 - 49	144	23	-	1	1	1	1
50 - 74	49	93	27	6	8	10	9
75 - 99	22	81	86	59	66	65	43
100 - 124	25	26	80	91	76	74	86
125 - 149	7	14	20	44	53	45	54
150 - 174	8	15	9	16	14	18	19
175 - 199	4	11	8	6	6	7	5
200 - 224	1	22	20	8	2	3	4
225 - 249	1	13	7	6	3	4	4
250 - 274	1	8	14	6	4	-	1
275 - 299	-	2	3	3	1	3	1
300 - 324	2	1	9	2	3	1	4
325 - 349	-	1	2	-	3	-	1
350 - 374	-	1	5	6	4	7	1
375 - 399	-	1	1	3	3	3	2
400 - 424	-	2	10	13	6	2	5
425 - 449	-	-	1	3	1	2	1
450 - 474	1	1	2	7	6	10	-
475 - 499	-	-	5	4	6	1	4
500 - 524	-	-	2	10	7	5	8
525 - 549	-	2	2	-	2	4	-
550 - 574	-	-	1	11	8	6	7
575 - 599	-	-	-	4	1	4	3
600 - 624	-	1	2	3	14	9	6
625 - 649	-	-	1	-	1	3	2
650 - 674	-	-	1	2	10	4	6
675 - 699	-	-	-	3	3	3	3
700 - 724	-	-	-	-	-	-	-
725 - 749	-	-	-	-	-	-	-
750 +	-	2	2	3	9	26	9

* Individual field cone indices were used in making the distributions. contrasted to the use of average indices as shown on the strength profiles of the previous figures.

TABLE V-4. RANGE OF CONE INDICES

	CHIVA CHIVA				ALBROOK FOREST			
	Natural Range		Most Frequently Ocurring Range (80% or more)		Natural Range		Most Frequently Ocurring Range (80% or more)	
	Seasons		Seasons		Seasons		Seasons	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Sfc	20-575	50-750+	25-200	100-300+	15-125	20-475	15- 75	25-175
3 in.	75-450	150-750+	100-250	750+	25-275	50-750+	25-125	50-275
6 in.	100-600	200-750+	125-300	750+	50-500	75-750+	50-150	75-425
9 in.	200-475	250-750+	200-475	750+	25-700	75-750+	50-175	75-575
12 in.	200-550	350-750+	200-475	750+	25-700	75-750+	50-175	75-675
15 in.	200-675	400-750+	200-475	750+	25-675	50-750+	50-200	75-675
18 in.	200-700	400-750+	200-500		25-700	75-750+	50-225	75-675

Moisture Content-Soil Strength Relations

The natural field strength of soils is measured in terms of the soil trafficability indices developed by WES: cone index, remolding index, and rating cone index. The cone penetrometer is used to measure the shearing resistance of the soil expressed as the cone index (CI). The gain or loss of soil strength to be expected under traffic is measured with the remolding equipment as described in Reference 10; the remolding index (RI) is the ratio of the remolded soil strength to its original strength as measured with the cone penetrometer. The cone index readings of undisturbed soil are multiplied by the remolding index to obtain the "rating cone index" (RCI) which is the strength rating of the soil under sustained traffic. All the curves plotted in this section of the report have been drawn in by eye, in order to emphasize the general trend. Therefore, they should not be considered as the final best-fit curves.

Moisture Content vs. Cone Index. Figure V-8 shows the cone index and moisture content data by 6-inch incremental layers for the two main sites. It is observed that lower soil strength is found at Albrook; the range of the most frequently occurring cone indices for each 3-inch incremental layer for the wet and dry seasons was pointed out previously in Table V-4. The graphs also show the greater strength exhibited by the soils with increasing depth. In general, the spread of the data about the trend line is less for the 0- to 6-inch layer, and the widest spread occurs in the 12- to 18-inch layer. The wider spread observed in the data at greater depths can be attributed in part to instrument and/or operator deficiencies. Figure V-9 combines cone index and soil moisture data for the 0- to 6-inch and 6- to 12-inch layers from the three satellite sites with those of the two main sites. The deviation of the Fort Sherman site data on the Atlantic side from those plotted for the sites on the Pacific side is clearly shown by these curves, however soil strength at the Fort Sherman site follows the same trend as at the other sites, but at higher soil moisture values. It is interesting to note the remarkable uniformity of the cone index and soil moisture data obtained for all the sites on the Pacific side of the Canal Zone where the data from the four sites plotted along the same general curve for both the 0- to 6- and 6- to 12-inch layers.

Moisture Content vs. Remolding Index. Figure V-10 graphically shows the apparent relationship between remolding index and moisture content for the 6- to 12-inch layer for the sites. Remolding tests were restricted to the 6- to 12-inch layer since that is considered the most critical for soil trafficability considerations. Figure V-11 shows a more significant plot of the data in which the relationship derived for each of the sites has been combined into a single composite graph. This graph demonstrates the inconsistent relationship between remolding index and moisture content, which does not follow any constant trend. A slight response of remolded soil strength to moisture content at the two main sites appears on the drier side of the graph. The significance of this is not great since remolding of the soil at low moisture content is not a limiting factor for soil trafficability. On the other hand, the soils at all sites

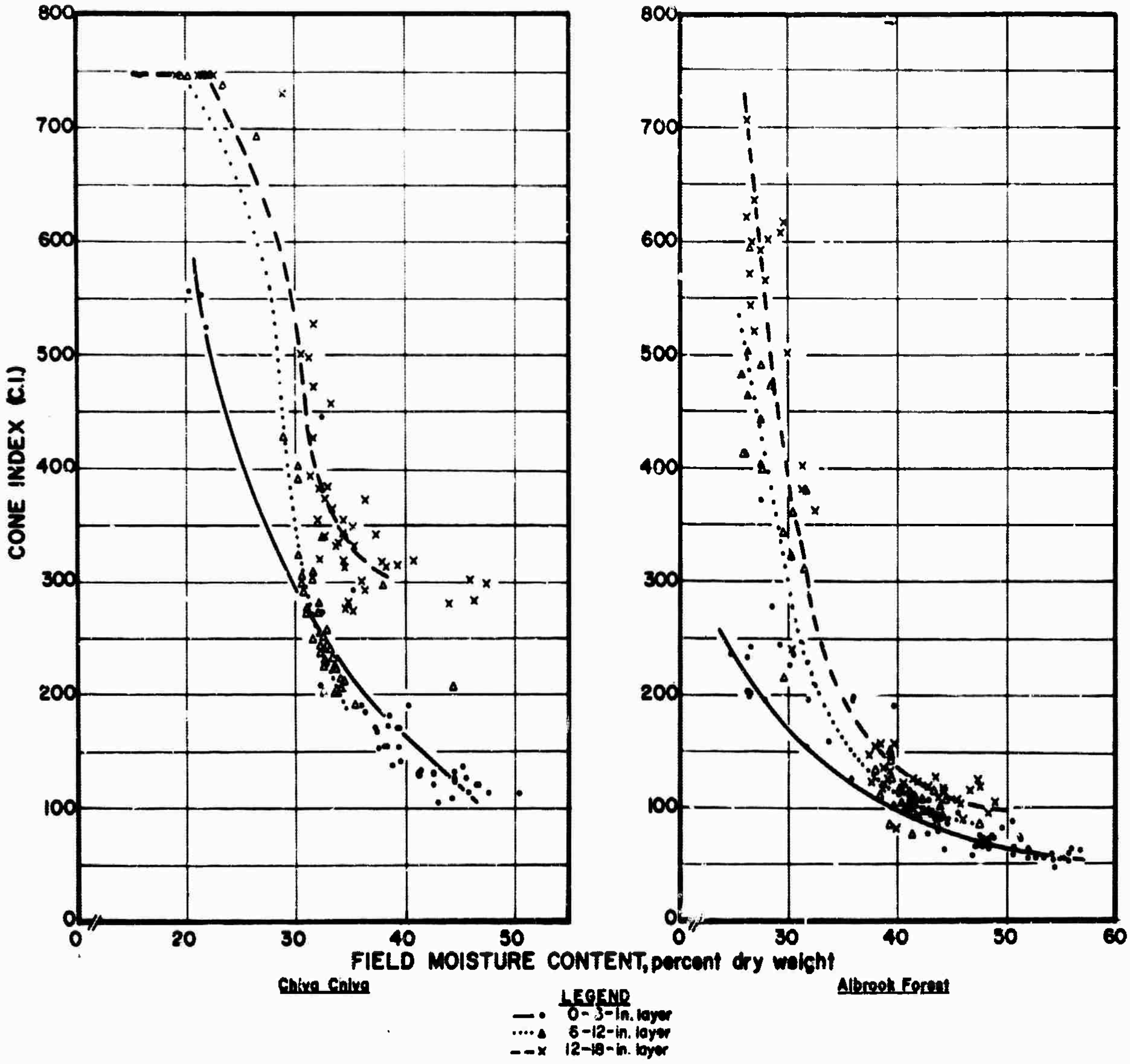

FIGURE V-8. CONE INDEX - SOIL MOISTURE RELATIONSHIP BY 6-INCH LAYERS, CHIVA CHIVA AND ALBROOK

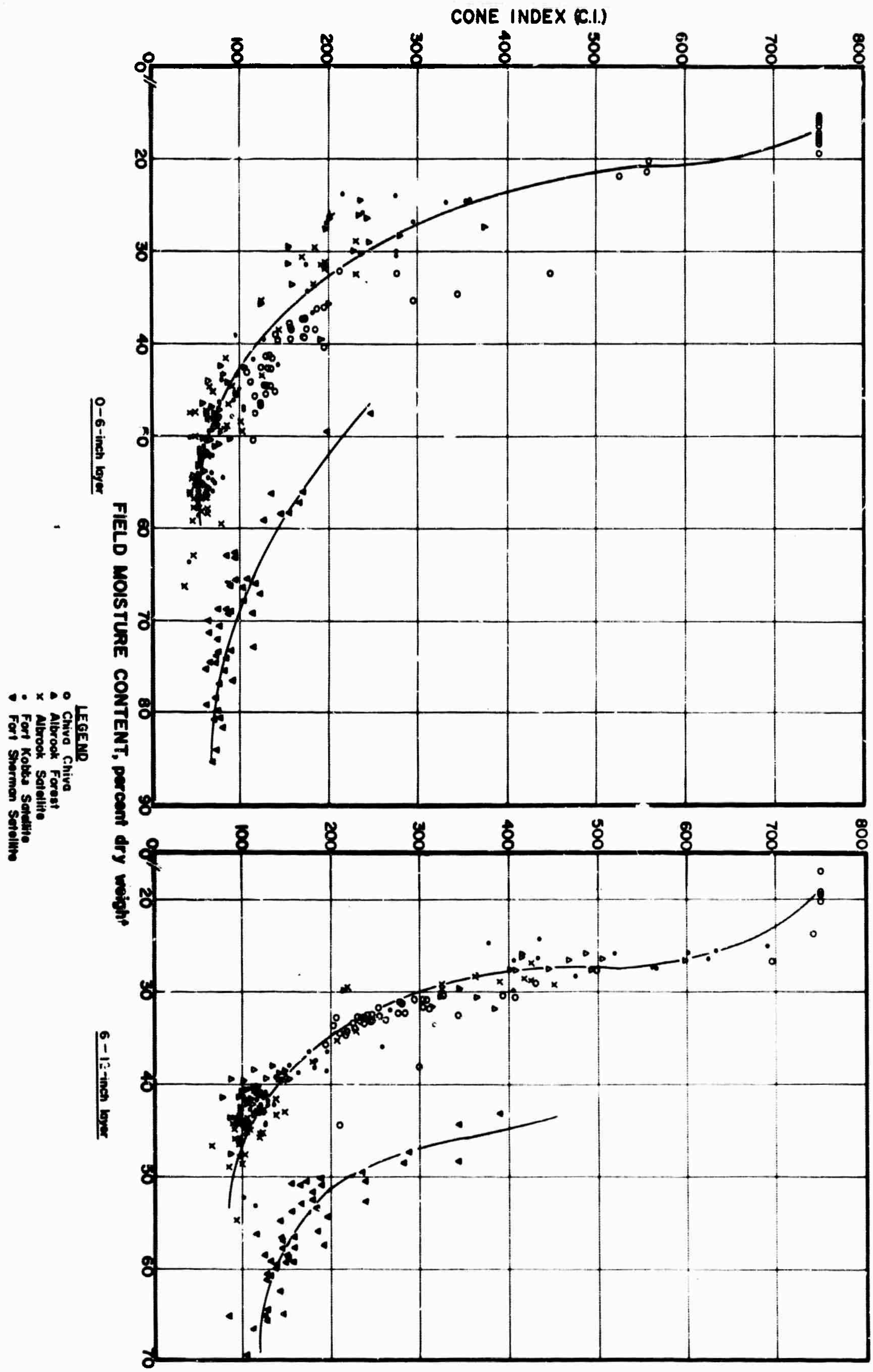

FIGURE V-9. COMBINED CONE INDEX - SOIL MOISTURE RELATIONSHIP FOR ALL SITES, 0 TO 6 AND 6 TO 12-INCH LAYERS.

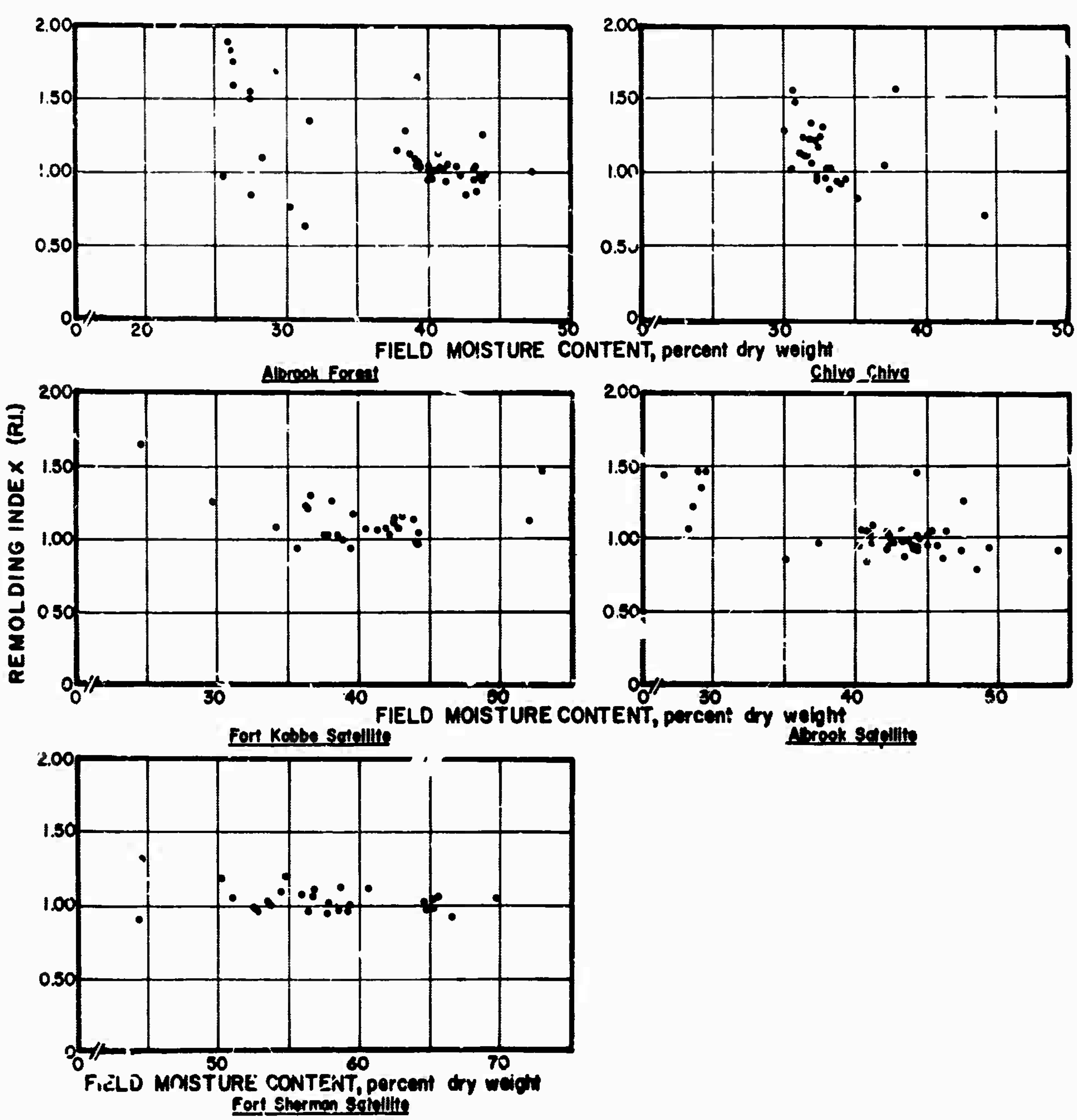

FIGURE V-10. REMOLDING INDEX - SOIL MOISTURE RELATIONSHIP FOR ALL SITES, 6 TO 12-INCH LAYER

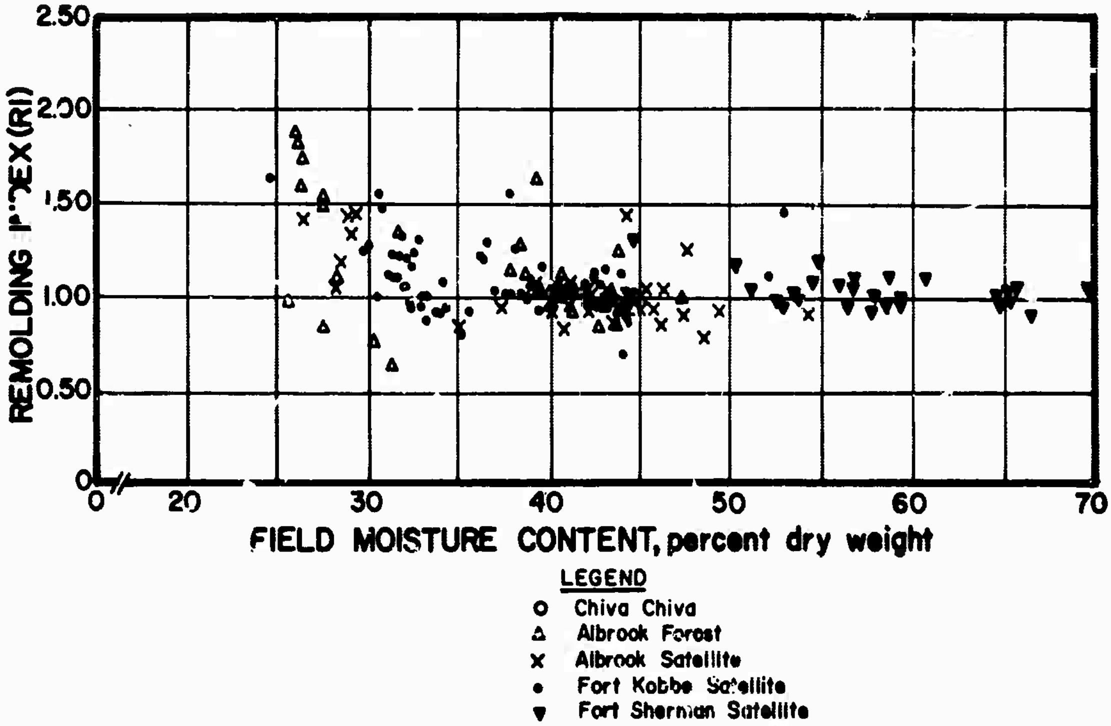

FIGURE V-11. COMBINED REMOLDING INDEX - SOIL MOISTURE RELATIONSHIP FOR ALL SITES, 6 TO 12-INCH LAYER

gained strength after remolding more often than not. The highest gains and losses in strength are exhibited by the soils at the two Albrook sites. In general however, remolding index values are close to unity.

Moisture Content vs. Rating Cone Index. Figure V-12 is a composite of all the rating cone indices computed for the 6- to 12-inch layer for the two main sites and the three satellite sites, using individual remolding index values as determined in the field. Except for the data from the Fort Sherman satellite site which exhibits a reduction in strength after remolding, the remaining data plot along the same general cone index - soil moisture relation established in Figure V-9. The apparent loss of strength of the soils at the Fort Sherman site is on the order of magnitude of 40 percent of the original strength. However when an average remolding index value is used, there appears to be no remolding effects of any of the five sites, the average value for each site having been determined by adding all individual field values and dividing by their total number. Figure V-12 shows the results obtained. If one compares this latter figure with Figure V-10, it is clearly seen that the data contained in both figures are scattered around the same point about the general trend line. This result is to be expected since apparently most of the remolding indices used to compute the rating cone indices did not vary significantly with remolding or with changes in soil moisture at any of the sites.

Moisture Concent - Dry Density Relations

Because of the limited data on hand at the time the previous report(1) was prepared, it was stated that the dry density of the soil appeared to be practically unaffected by changes in moisture content within the range studied. Further analysis has revealed the contrary to be true. Relationships between moisture content (percent dry weight) and dry density (pounds per cubic foot) are presented in Figure V-13 for the Chiva Chiva and Albrook Forest main sites, combined in 6-inch incremental layers. Figure V-14 shows the same relationships at the three satellite sites, for the 0- to 6- and 6- to 12-inch layers only. All the data plotted for the five sites tend to produce a hyperbolic curve in which dry density increases from the dry-end portion of the graph to a maximum moisture content, at which point further increments of moisture cause a lowering of the dry density of the soil. This behavior is consistent with that generally obtained from compacted soils in the laboratory in the determination of the maximum density and optimum moisture content. Obviously, dry density is least at the 0- to 6-inch layer where physical conditions are favorable to granulation and soil porosity. Reduction in pore space due to compaction effects exerted by overlying layers is reflected in higher densities at the lower depths. However, densities obtained from soil samples collected at Chiva Chiva showed higher results for the 6- to 12-inch layer than those obtained for the 12- to 18-inch layer. This apparent anomaly may be due in part to slight variations in mineralogical composition and textural differences between the two layers. It was noted, for example, that at the 12- to 18-inch layer ferruginous concretions were present in greater quantity than in the upper layers. At Albrook, on the other hand, dry

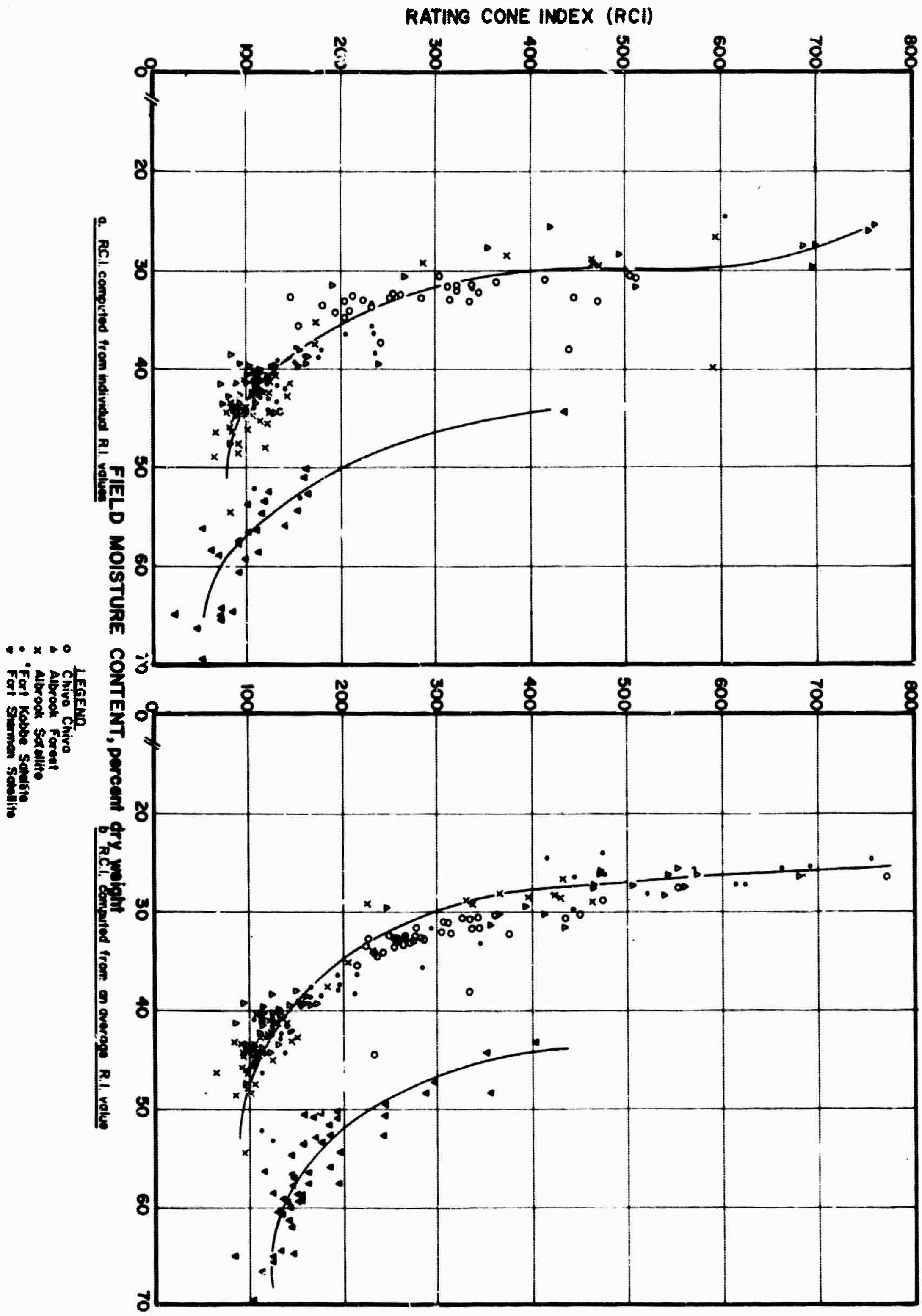

FIGURE V-12. COMBINED RATING CONE INDEX - SOIL MOISTURE RELATIONSHIP FOR ALL SITES, 6 TO 12-INCH LAYER

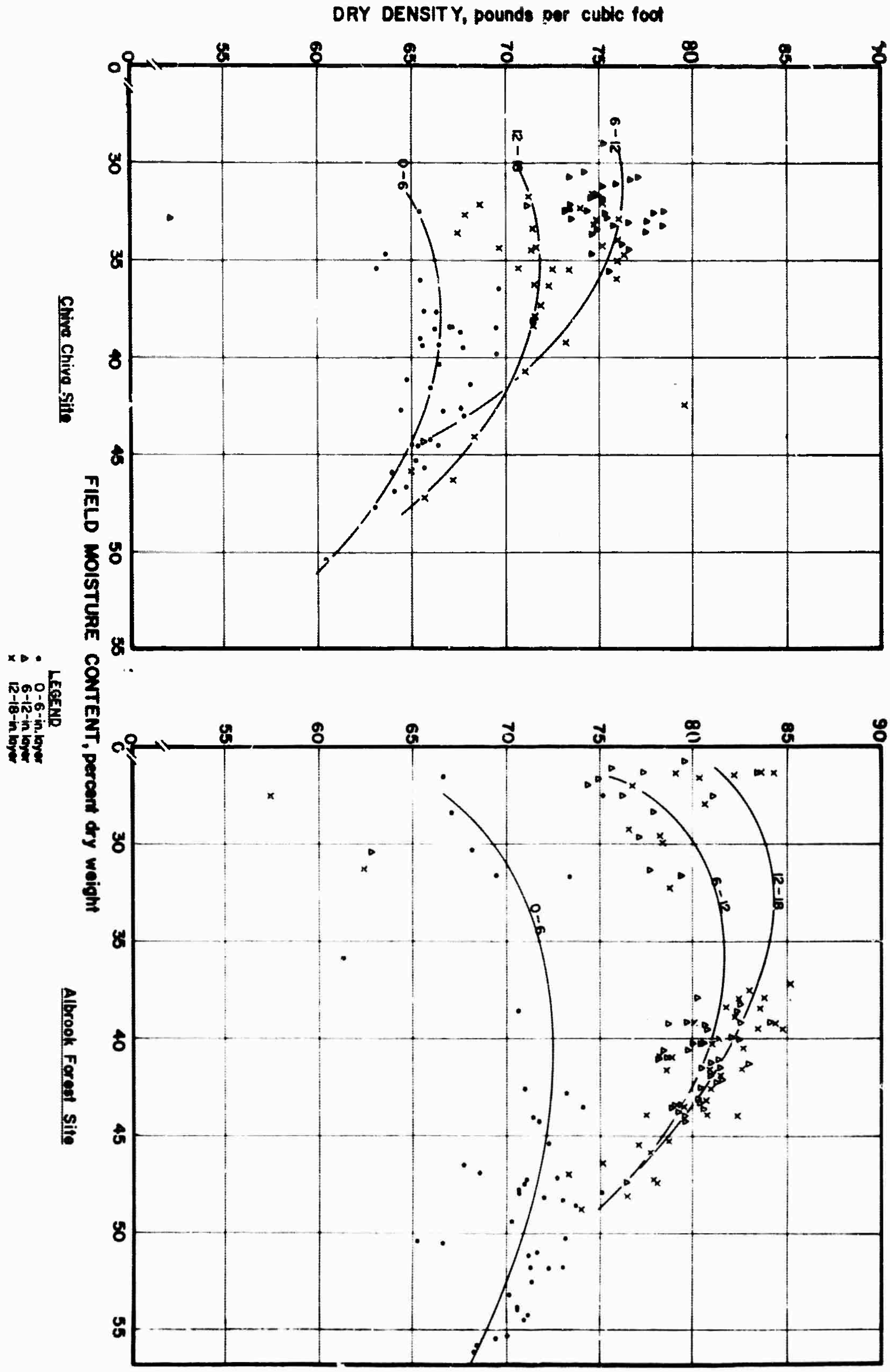

FIGURE V-13. DRY DENSITY - SOIL MOISTURE RELATIONSHIP BY 6-INCH LAYERS, CHIVA CHIVA AND ALBROOK FOREST SITES.

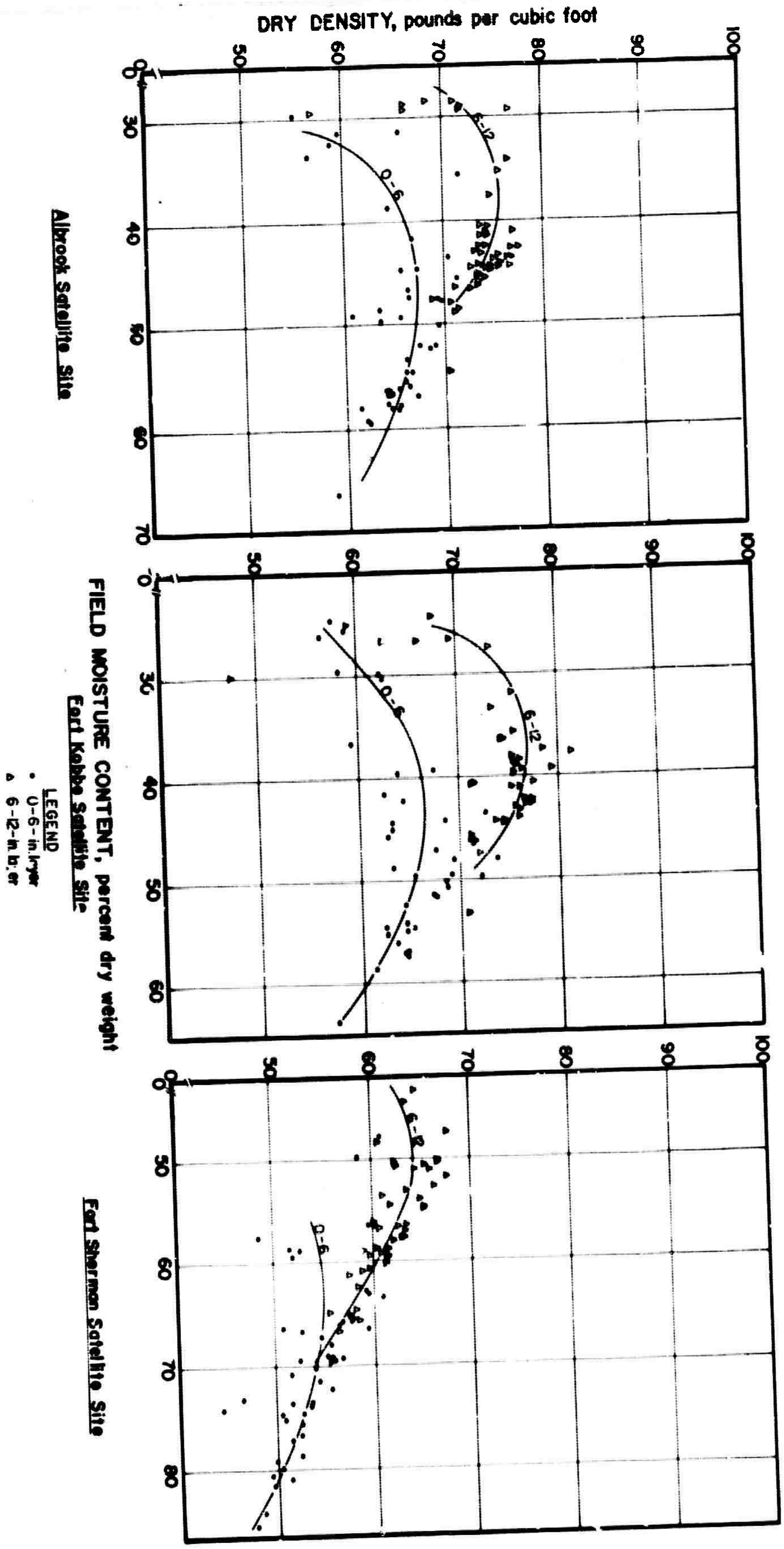

FIGURE V-14. DRY DENSITY - SOIL MOISTURE RELATIONSHIP BY 6-INCH LAYERS, ALBROOK, FORT KOBBE, AND FORT SHERMAN SATELLITE SITES

densities do tend to increase with depth. However, the differences observed between the 6- to 12- and 12- to 18-inch layers, are slight and in most instances, particularly between about 37 percent and 45 percent natural field moisture content, density data obtained for the two lowermost layers tend to converge. Soils at the three satellite sites follow the same general trend and behavior as described for the Albrook Forest site.

PART VI. VEGETATION

Progress was made on the vegetation task of the Data Base project during the current reporting period despite the fact that the Tropic Test Center staff position reserved for a botanist was vacant. This position was filled in May 1967, and research results are expected to be significantly augmented during the next reporting period.

Further analysis has been carried out on the forest litter study which was discussed in the previous project report. Data collected through December 1966 are utilized in the present report.

A brief study on seedlings as well as seed germination and storage was carried out in conjunction with the plant collection activities. Results of this limited study are presented in Appendix B.

The vegetation inventory of the Albrook Forest Site has been updated and revised in format to facilitate machine storage of data. The new inventory is presented in Appendix C.

Forest Litter*

Introduction

The forest litter investigations of the Data Base project provide information concerning the composition and the quantity of litter fall within several humid tropic forests. Forest litter is defined as the recently fallen, non-decomposed ground accumulation under a forest canopy of leaves, seeds, fruits, insect and animal forms, and debris such as animal and bird droppings, sap, and other particulate material. The type, amount, and time of fall of litter in the forest influences ground cover, microbial and insect activity, chemical and particulate matter in the atmosphere, and the conduct of exposure tests in the study of materials deterioration. Observation of contamination, infestation, and damage to fallen leaves and flowers reveals intensity of activity of macro and microfauna. The duration of leaf, flower, and fruit fall can provide a supplementary observation of phenological events usually measured visually and photographically.

Litter samples were collected both in litter pans and directly from the ground. That which fell into the pans provided a basis for measuring rates of litter accumulation; while collections of accumulated litter deposits from the ground provided a measure of the amount of litter on the forest floor throughout the sampling period. Weights of the pan litter samples and their components (leaves, seeds, fruits, insect and animal forms, and various other kinds of debris) were determined. The ground

* This section was prepared by Dr. Robert S. Hutton, Biological Scientist

litter was processed to determine weights, moisture content, and microbial and arthropod content.

The previous Semiannual Report[1] contained a preliminary report of observations on forest litter. Data presented here are from an expanded investigation started at the beginning of the report period.

Pan Litter

This report on pan litter contains data collected in two tropical forest types. The forest types examined were at the Albrook Forest site, a semideciduous tropical forest, and a site near Fort Sherman (see map, Figure II-1), a more nearly evergreen tropical forest. Data covered include only three months (Oct-Dec, 66) for the Albrook site and two months (Nov, Dec 66) for the Fort Sherman site. A later report will contain data on litter collected in the remainder of the period as well as information on mineral content of the litter and mineral loss of decaying leaves.

Data Collection Methods

Pan litter collection was greatly expanded in October 1966. Frequency of collection was the same - once each week at each site - but the number of samples was increased. Thirty screen-wire traps or pans, one meter square, were placed at each site in randomized locations under the canopy compared to only five pans at the Albrook forest site in the previous period. After collection, the litter from each pan was weighed, then dried at 100-110 C for 24 hours and re-weighed. Both weights were recorded. The dry litter was sorted and the weight of leaves, fruits and seeds, branches, and debris recorded separately. As species were not known at separation, each species and part was denoted by a number. Later these will be identified and named.

Results

Weights of pan litter before drying are given in Table VI-1. Total dry weights of various components of the litter collected at each site are shown in Table VI-2. Dry weights of the fruits and seeds collected in each pan at the two sites are shown in Table VI-3. Because the data cover such short periods, only the most general sort of conclusions can be drawn from them. Leaf fall, as well as total litter fall, was, as expected, greater in the Albrook forest where trees are deciduous. Both total litter and leaf fall at Fort Sherman were highly variable as compared with Albrook. The coefficient of variation for differences between pans at Sherman is almost double the figure obtained at Albrook. Fruit and seed fall at Fort Sherman is negligible.

Ground Litter

Data Collection Methods

Investigations of litter on the Albrook forest floor continued using

TABLE VI-1. PAN LITTER WEIGHT BEFORE DRYING
(in grams)

ALBROOK FOREST SITE

PAN No.	1	2	3	4	5	6
LEAF WEIGHT	63.60	98.75	63.15	61.60	72.80	106.75
TOTAL WEIGHT	183.05	246.80	91.75	96.40	84.70	167.15

PAN No.	7	8	9	10	11	12
LEAF WEIGHT	71.20	59.85	62.75	115.73	61.61	94.05
TOTAL WEIGHT	190.85	68.75	70.95	131.18	104.86	136.30

PAN No.	13	14	15	16	17	18
LEAF WEIGHT	35.05	82.30	78.00	55.15	40.35	60.60
TOTAL WEIGHT	45.80	122.85	116.95	117.20	57.80	90.85

PAN No.	19	20	21	22	23	24
LEAF WEIGHT	76.95	94.05	42.45	146.55	81.25	133.70
TOTAL WEIGHT	102.25	118.15	54.60	154.95	127.20	134.90

PAN No.	25	26	27	28	29	30
LEAF WEIGHT	70.20	82.63	91.50	84.55	82.65	40.80
TOTAL WEIGHT	83.20	292.98	133.80	116.55	121.80	64.65

ALL PANS

	GRAND TOTAL	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION
LEAF WEIGHT	2310.57	77.02	26	.33
TOTAL WEIGHT	3631.22	121.04	54	.45

TABLE VI-1. PAN LITTER WEIGHT BEFORE DRYING (Cont'd)
(in grams)

FORT SHERMAN SITE

PAN No.	31	32	33	34	35	36
LEAF WEIGHT	44.30	66.45	37.10	44.40	40.10	49.85
TOTAL WEIGHT	94.65	86.80	38.90	85.60	70.05	56.35
PAN No.	37	38	39	40	41	42
LEAF WEIGHT	59.15	207.25	22.40	58.30	31.00	16.45
TOTAL WEIGHT	63.40	215.85	29.05	113.60	35.25	17.80
PAN No.	43	44	45	46	47	48
LEAF WEIGHT	45.45	25.90	28.45	15.80	9.85	26.15
TOTAL WEIGHT	53.95	40.60	92.60	16.35	12.40	59.60
PAN No.	49	50	51	52	53	54
LEAF WEIGHT	24.30	14.75	42.00	42.00	63.00	38.20
TOTAL WEIGHT	55.85	20.95	174.75	61.60	127.50	51.65
PAN No.	55	56	57	58	59	60
LEAF WEIGHT	46.30	39.50	28.00	40.55	28.65	41.40
TOTAL WEIGHT	86.45	85.80	49.00	53.55	105.95	54.65

ALL PANS

	GRAND TOTAL	MEAN	STANDARD DEVIATION	COEFFICIENT OF VARIATION
LEAF WEIGHT	1277.00	42.57	33.6	.79
TOTAL WEIGHT	2110.70	70.36	44	.63

TABLE VI-2. DRY WEIGHT OF PAN LITTER
(in grams)

ALBROOK FOREST SITE

MONTH	LEAVES	FRUITS AND SEEDS	BRANCHES	DEBRIS	TOTAL
OCT.	332.59	4.50	45.55	68.80	451.44
NOV.	1,109.63	6.95	405.60	228.00	1,750.18
DEC.	868.35	2.20	142.25	192.90	1,205.70
TOTAL	2,310.57	13.65	593.40	489.70	3,407.32

FORT SHERMAN SITE

MONTH	LEAVES	FRUITS AND SEEDS	BRANCHES	DEBRIS	TOTAL
NOV.	439.50	0.35	44.95	280.20	765.00
DEC.	837.50	0	46.80	236.15	1,345.70
TOTAL	1,277.00	0.35	91.75	516.35	2,110.70

TABLE VI-3. DRY WEIGHT OF FRUITS AND SEEDS FOUND MONTHLY, BY PAN, 1966

ALBROOK FOREST SITE

PAN #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
OCT.	0.30	0.25	0	0	0	0	0	0	0	0	0	0	0	0	0	
NOV.	1.05	0.70	0	0	0	0.10	0	0	0	0.10	0.10	0	0	0	0	
DEC.	0	0.25	0	0.05	0.05	0	0.15	0.05	0	0	0.10	0	0	0	0	
TOTAL	1.35	1.20	0	0.05	0.05	0.10	0.15	0.05	0	0.10	0.20	0	0	0	0	
PAN #	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	TOTAL
OCT.	0	0	0.10	0	0	0.45	0.10	0	0	0	3.20	0.10	0	0	0	4.50
NOV.	0.15	0.40	1.90	0	0	1.05	0	0.05	0	0	1.15	0.20	0	0	0	6.95
DEC.	0	0	0.30	0	0	0.70	0	0	0	0	0.45	0.10	0	0	0	2.20
TOTAL	0.15	0.40	2.30	0	0	2.20	0.10	0.05	0	0	4.80	0.40	0	0	0	13.65

FORT SHERMAN SITE

PAN #	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	
NOV.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
DEC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
TOTAL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
PAN #	46	47	48	49	50	1	52	53	54	55	56	57	58	59	60	TOTAL
NOV.	0	0	0	0	0	0	0	0	0	0.35	0	0	0	0	0	0.35
DEC.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0	0	0	0	0.35	0	0	0	0	0	0.35

the same methods described in the previous report. Litter was collected every two weeks from ten randomly chosen plots of 200 square cm each. The plots were newly selected each time, independently of the plots previously used. All the litter at each plot was picked up and immediately sealed in a plastic bag to prevent moisture loss and escape of arthropods. A separate collection was made at each plot for microbial analysis, in which a very small amount of litter was aseptically collected to form one composite sample for the entire site area.

Analytical Methods

The wet weight of each individual bulk collection was determined, after which the collected material was placed in a Berlese funnel for 48 hours to remove the arthropods. After the arthropods had been separated, the litter was dried at 50 C for 24 hours and weighed. This weight was recorded as dry weight of the litter. Finally, collections were heated at 450 C for 24 hours and the residual ash weighed and stored for possible radiation analysis. The aseptically collected material for microbial analysis was blended, then plated on nutrient agar and on carrot agar. One-ml aliquots of each dilution of the sample were added to tubes of the melted agars and then transferred to petri plates and incubated for five days at 28 C. Bacterial colonies grow on the nutrient agar, while carrot agar encourages the growth of fungi.

Results

Gravimetric Characteristics of Ground Litter. In order to cover a period of sufficient length to be useful, data from November 1965 through December 1966 are included in this section. Table VI-4 contains data on wet, dry, and ash weights, as well as the moisture and ash percentages for all the samples collected for the period. In this presentation of the data, the collections from the first five and the second five of the ten 200-square-cm plots were combined to form two samples. Standard deviations were calculated for the six samples obtained in each three collecting periods.

Figure VI-1 plots the mean values and standard deviations for each recorded value for dry and ash weights as well as the values for moisture percentage in the collected litter. The litter dry weight remained constant from November through March and increased significantly about mid-April to the middle of June. The time of increase coincides with the start of the rainy season. Ash weight decreased significantly from November through March, and then increased sharply during April and May. Litter moisture decreased to a minimum in the February-March period and then rose to a fairly constant value approaching 65 percent for the remainder of the time of observation.

Differences between samples for all of the observations indicate a distinct lack of homogeneity in the occurrence of ground litter at the Albrook site. Inspection of the area to determine whether this variability

TABLE VI-4. GROUND LITTER SAMPLES: ALBROOK FOREST SITE
WHOLE PLOT SEQUENTIAL SAMPLING.

Weights given in grams per 1000 cm^2

Collection Date	Sub-Sample	Wet Litter Weight	Dry Litter Weight	Dry Litter % Water	Ash Weight	Ash % Dry Weight
26 Nov 65	1	236	63.6	72.8	13.7	21.9
	2	355	108	69.8	31.0	29.0
10 Dec 65	1	154	47.3	69.5	12.4	25.5
	2	313	91.8	70.2	33.8	36.9
23 Dec 65	1	218	75.7	65.5	29.6	39.2
	2	117	40.8	64.9	17.6	43.9
7 Jan 66	1	158	61.8	61.1	21.9	36.1
	2	150	57.7	61.3	18.8	32.7
20 Jan 66	1	150	78.7	46.4	15.5	20.2
	2	65.4	39.5	38.4	7.13	10.8
4 Feb 66	1	157	119	24.3	22.5	14.4
	2	97.1	72.5	25.2	11.9	12.3
18 Feb 66	1	91.6	43.8	52.2	9.7	10.7
	2	112	83.2	25.9	10.7	9.5
4 Mar 66	1	123	90.1	26.9	9.9	11.0
	2	106	76.0	28.5	13.1	12.3
21 Mar 66	1	81.0	61.2	24.3	7.6	12.4
	2	149	122	17.7	24.4	20.0

TABLE VI-4. GROUND LITTER SAMPLES: ALBROOK FOREST SITE
WHOLE PLOT SEQUENTIAL SAMPLING (cont'd)

Collection Date	Sub-Sample	Wet Litter Weight	Dry Litter Weight	Dry Litter % Water	Ash Weight	Ash % Dry Weight
1 Apr 66	1	185	64.7	64.8	11.2	17.3
	2	115	67.2	40.8	13.4	19.9
15 Apr 66	1	138	106	23.4	13.8	13.1
	2	97.4	74.5	23.4	11.7	15.7
29 Apr 66	1	167	85.1	49.0	11.9	13.9
	2	217	109	49.7	22.1	20.2
13 May 66	1	356	120	66.6	28.3	23.6
	2	455	155	65.9	35.4	22.8
27 May 66	1	291	99.5	55.6	36.4	36.6
	2	321	122	62.0	37.6	30.8
10 Jun 66	1	315	114	63.5	35.9	31.2
	2	412	153	62.9	50.3	32.9
24 Jun 66	1	202	75.5	62.6	15.9	21.1
	2	138	62.9	54.4	17.6	28.1
9 Jul 66	1	142	58.2	59.5	24.1	16.7
	2	308	124	59.7	50.6	16.4
22 Jul 66	1	282	101	64.2	38.6	38.2
	2	174	67.1	61.5	22.1	32.9
5 Aug 66	1	141	56.8	59.6	14.5	25.5
	2	215	80.7	62.6	18.4	22.8

TABLE VI-4. GROUND LITTER SAMPLES: ALBROOK FOREST SITE
WHOLE PLOT SEQUENTIAL SAMPLING (cont'd)

Collection Date	Sub-Sample	Wet Litter Weight	Dry Litter Weight	Dry Litter % Water	Ash Weight	Ash % Dry Weight
19 Aug 66	1	179	53.3	70.4	14.1	26.4
	2	156	51.6	[illegible]	14.7	28.5
2 Sep 66	1	116	44.8	60.5	12.0	26.8
	2	131	40.9	68.5	13.0	31.8
16 Sep 66	1	145	53.1		19.6	
	2	140	62.2		14.7	
30 Sep 66	1	257	61.1		24.2	
	2	227	68.5		21.8	
15 Oct 66	1	141	50.6		8.5	
	2	191	80.9		22.9	
29 Oct 66	1	80.8	39.5		8.38	
	2	119	52.9		14.5	
26 Nov 66	1	95.4	32.1		10.4	
	2	93.6	25.9		7.75	
10 Dec 66	1	77.7	26.4		7.56	
	2	95.5	36.9		6.9	

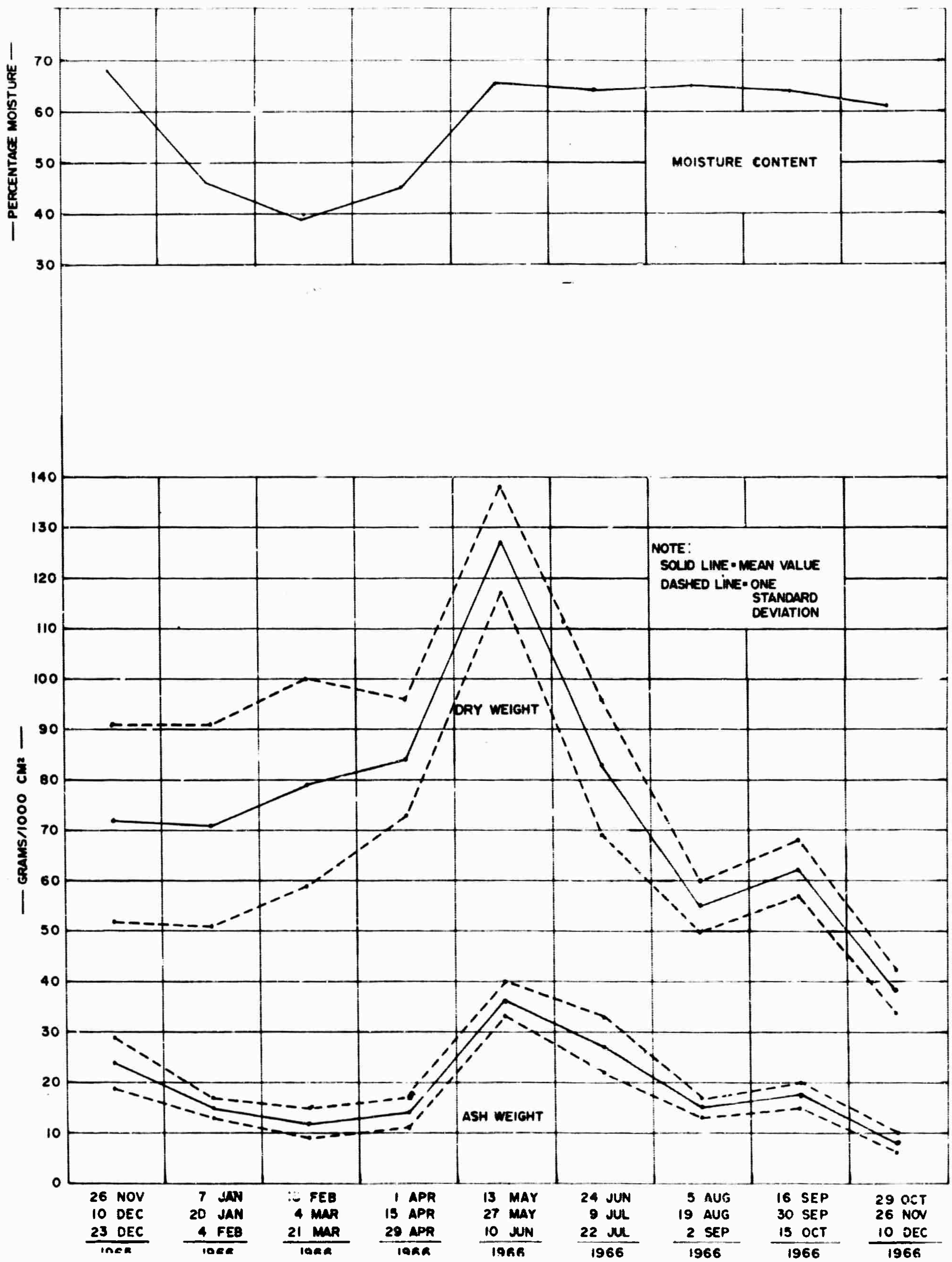

FIGURE VI-1. GROUND LITTER SAMPLES, ALBROOK FOREST SITE: MOISTURE CONTENT, ASH WEIGHT, DRY WEIGHT

was random or whether it might be explained on the basis of some characteristic of the site led to the observation that the site can reasonably be divided into three subordinate zones as shown in Figure VI-2, based on the distribution of the larger trees.

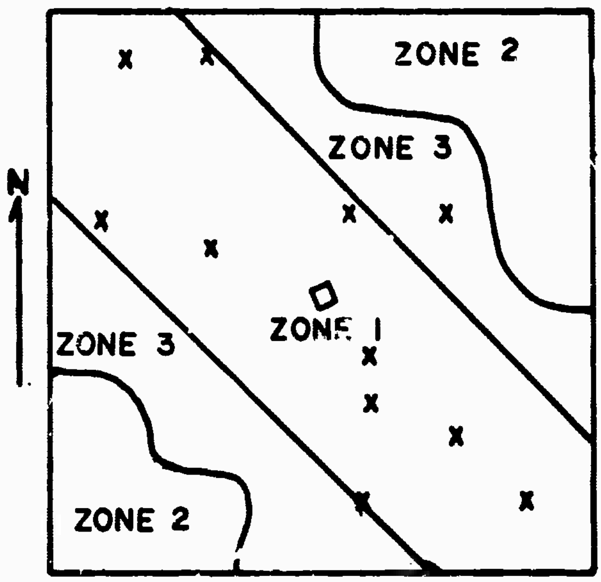

FIGURE VI-2. LOCATION OF TREES WITH TRUNK DIAMETER OF 65 CM OR GREATER, ALBROOK FOREST SITE

With only one exception, all trees of 65-cm trunk diameter and over are located in Zone 1. Zone 2, by contrast, is relatively distant from any large trees, so shading and rooting influences are reduced. Zone 3 lies under the crowns of the large trees and is close enough to be influenced by their shade and the presence of large roots.

Data presented in Table VI-5 and Figure VI-3 compare the litter samples taken from the whole plot against samples from each of the three zones. For comparative purposes, and to minimize the effect of the variations occurring with smaller samples, litter sample collections from three sequential collection dates have been aggregated from weight determinations of the wet and dry litter and ash residue. Except for a short interval early in the rainy season, there is a tendency for dry and ash weights to be higher in Zone 1 than in either Zone 2 or 3.

However, in only a few instances (those marked with an asterisk in Table VI-5) are the differences greater than one standard deviation value obtained for the whole plot values of the samples. The tendency for wet, dry, and ash weight values to be relatively low for Zone 1 during the May-June early rainy season period and relatively high for all the rest of the year may be significant. Increased moisture conducted down large tree

TABLE VI-5. COMPARISON OF WHOLE PLOT WITH ZONED LITTER SAMPLES

Weight given in grams per 1000 cm^2; Standard Deviation of Whole Plot in ( ).

Sample Collection Dates	Sample Location	Wet Litter	Dry Litter			Ash
		Weight (SD)	Weight (SD)	% Water	Weight (SD)	% Dry Weight
1965 26 Nov - 10 Dec - 23 Dec	Whole Plot	232 (82)	71.1 (23.5)	68.8	23.0 (8.7)	32.6
	Zone 1	291	87.0	70.1	28.9	33.2
	Zone 2	205	61.0	70.2	15.7	25.7
	Zone 3	166	58.0	65.0	15.2	26.2
1966 7 Jan - 20 Jan - 11 Feb	Whole Plot	129 (35)	71.5 (24.3)	45.7	16.3 (5.6)	22.8
	Zone 1	141	73.0	48.2	17.5	23.9
	Zone 2	121	74.5	38.4	14.1	18.9
	Zone 3	119	64.5	45.8	16.8	26.0
1966 18 Feb - 4 Mar - 21 Mar	Whole Plot	110 (22)	79.3 (24.5)	39.3	12.5 (5.6)	15.8
	Zone 1	150*	117*	27.7	18.7*	15.9
	Zone 2	103	74.5	38.9	9.30	12.4
	Zone 3	70.0*	48.2*	45.2	9.30	19.2
1966 1 Apr - 15 Apr - 29 Apr	Whole Plot	153 (41.1)	84.3 (17.6)	44.9	14.0 (3.8)	16.6
	Zone 1	164	93.5	43.0	26.4*	28.2
	Zone 2	134	90.0	32.9	13.7	15.2
	Zone 3	122	71.0	41.8	11.3	15.9
1966 13 May - 27 May - 10 Jun	Whole Plot	358 (57)	128 (21)	64.2	37.1 (7.3)	29.0
	Zone 1	323	110	65.9	31.3	28.4
	Zone 2	418	150*	64.1	44.3	29.5
	Zone 3	356	132	62.9	39.5	29.9

TABLE VI-5. COMPARISON OF WHOLE PLOT WITH ZONED LITTER SAMPLES (cont'd)

Sample Collection Dates	Sample Location	Wet Litter Weight (SD)	Dry Litter Weight (SD)	Dry Litter % Water	Ash Weight (SD)	Ash % Dry Weight
1966 24 Jun - 9 Jul - 22 Jul	Whole Plot	208 (65)	81.6 (23.8)		28.1 (12.4)	
	Zone 1	272	100	63.2	35	35
	Zone 2	174	70.5	59.8	20.2	28.7
	Zone 3	168	79.5	52.7	29.0	36.5
1966 5 Aug - 9 Aug - 2 Sept	Whole Plot	156 (33)	54.6 (12.8)	65.3	14 (1.5)	25.6
	Zone 1	181	93*	48.6	16.4*	17.6
	Zone 2	164	62.5	62.1	15.1	24.1
	Zone 3	118*	42.1*	64.3	11.5*	27.3
1966 16 Sept - 30 Sept - 15 Oct	Whole Plot	[illegible] (55)	62.7 (10.5)	65.8	18.6 (5.2)	[illegible]
	Zone 1	204	68.0	66.7	22.5	30.9
	Zone 2	136	42.8*	68.5	12.0*	28.0
	Zone 3	169	63.5	62.1	16.9	26.6
1966 29 Oct - 26 Nov - 10 Dec	Whole Plot	96.3 (13)	37.5 (8.9)	61.0	9.3 (2.3)	24.8
	Zone 1	80*	47.0*	41.2	7.75	16.4
	Zone 2	111*	43.0	61.4	10.6	24.7
	Zone 3	92.0	35.3	61.6	9.25	26.2

* Indicates those zonal values which differ by more than one Standard Deviation (SD) from the whole plot values.

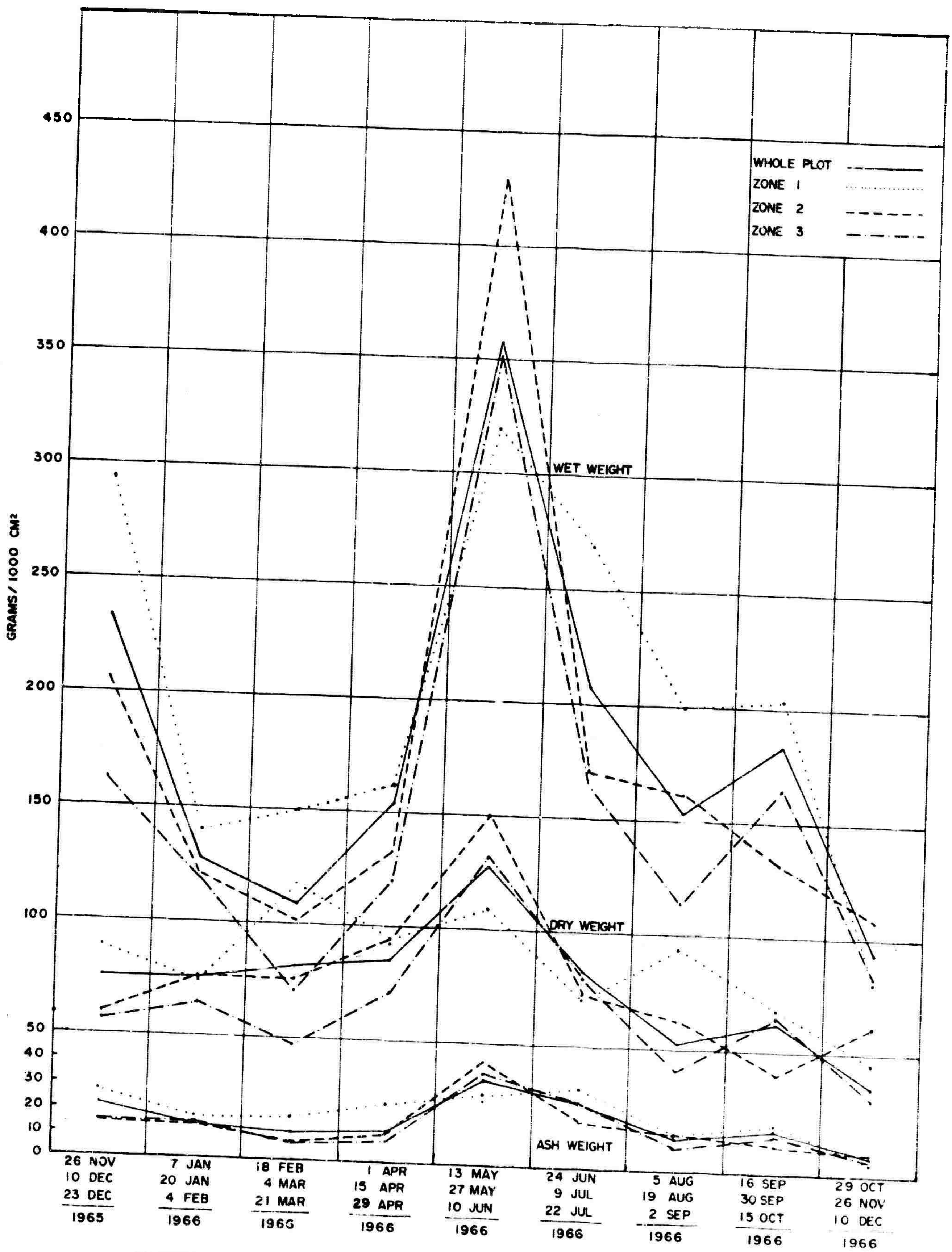

FIGURE VI-3. GROUND LITTER, ALBROOK FOREST SITE: WHOLE PLOT AND ZONAL LITTER ACCUMULATION

trunks and the increased soil-root activity which should characterize Zone 1 could account for an accelerated decomposition of litter in that area.

Arthropods in Ground Litter. The total number of arthropods in each collection of ground litter is recorded. Collections have been retained for future classification by an entomologist. The enumerations of the arthropods collected is less than 25 percent complete; however, at least two of each of the ten collections for each period have been examined. The values given for each collection period in Table VI-6 are the means of 2 to 8 subsamples from 200-square-cm areas. Subsamples selected for preliminary examination were taken randomly from the 30 subsamples collected in each of the periods indicated.

TABLE VI-6. NUMBER OF ARTHROPODS FOUND IN 200-CM^2 PLOTS OF ALBROOK FOREST GROUND LITTER

Collection Date - 1966	Sub-Sample Values	Mean
7 Jan - 20 Jan - 4 Feb	81 50 90 87	77
18 Feb - 4 Mar - 21 Mar	71 77 72 185	101
1 Apr - 15 Apr - 29 Apr	56 56	56
13 May - 27 May - 10 Jun	64 78	71
24 Jun - 9 Jul - 22 Jul	61 89 117 133 262 181	140
5 Aug - 19 Aug - 2 Sep	352 93 55 66 110 130	134
16 Sep - 30 Sep - 15 Oct	211 87 55 102 192 210	142
29 Oct - 26 Nov - 10 Dec - 24 Dec	79 43 65 51 67 35 157 98	74

Maximum variability between subsamples appears in the periods June through October. This is also the time in which maximum numbers of arthropods are present. As noted above this period is also characterized by maximum dry weight of ground litter and high moisture content.

All of the subsamples collected in the January-February interval were counted. Examination of these data by "zone" (see Figure VI-2) did not indicate any relationship between zone and the number of arthropods present. During these periods of collection the whole-plot mean for arthropods/200 square cm was 77 ± 25. Arthropods found in the collections for Zones 1, 2, and 3 were 79, 86, and 69 respectively. Even the number 86 is not indicative of a significant zone difference, because one sample which contained 250 very small ants was entirely responsible for the variation from the mean.

Microbiological Observations on Ground Litter. Table VI-7 lists numbers of bacteria and fungi found in the composite samples of ground litter for each of the collecting periods. Numbers vary so greatly that few, if any, seasonal trends can be observed.

TABLE VI-7. VIABLE FUNGI AND BACTERIA RECOVERED FROM SAMPLES OF ALBROOK FOREST GROUND LITTER

Collection Date	Bacteria	Fungi
14 Dec 65	121×10^{6} /gram	500×10^{5} /gram
23 Dec	9 " "	34 " "
7 Jan 66	300 " "	340 " "
20 Jan	800 " "	- - -
4 Feb	105 " "	- - -
18 Feb	173 " "	21 " "
4 Mar	12 " "	3 " "
21 Mar	74 " "	5 " "
5 Apr	58 " "	3 " "
19 Apr	490 " "	74 " "
29 Apr	101 " "	92 " "
13 May	45 " "	30 " "
27 May	125 " "	12 " "
10 Jun	158 " "	53 " "
24 Jun	239 " "	68 " "
14 Jul	76 " "	19 " "
22 Jul	5 " "	37 " "
5 Aug	179 " "	18 " "
19 Aug	291 " "	50 " "
6 Sep	1960 " "	25 " "
19 Sep	670 " "	27 " "
3 Oct	57 " "	43 " "
20 Oct	510 " "	300 " "
23 Nov	40 " "	40 " "
2 Dec	43 " "	5 " "
27 Dec	80 " "	65 " "

The mean values of each three weeks of collection were plotted in an attempt to determine whether there are seasonal trends (Figure IV-4.) Peaks of both microbial and fungal content in samples are indicated. However, in all instances where values result in peaks on the curve, the variation between samples is such that the values and their standard deviations are almost equal.

On the basis of these data it is evident that the investigation has not been very successful. Procedures for future work should involve more samples, or larger samples - or both. Since the interest in microbial content of litter is related to decomposition rate of the litter, future work might well take the form of observing effects of microorganisms present. Perhaps this could be accomplished by determining rates of decomposition or heat evolution in composts of large samples of collected litter maintained under standard conditions.

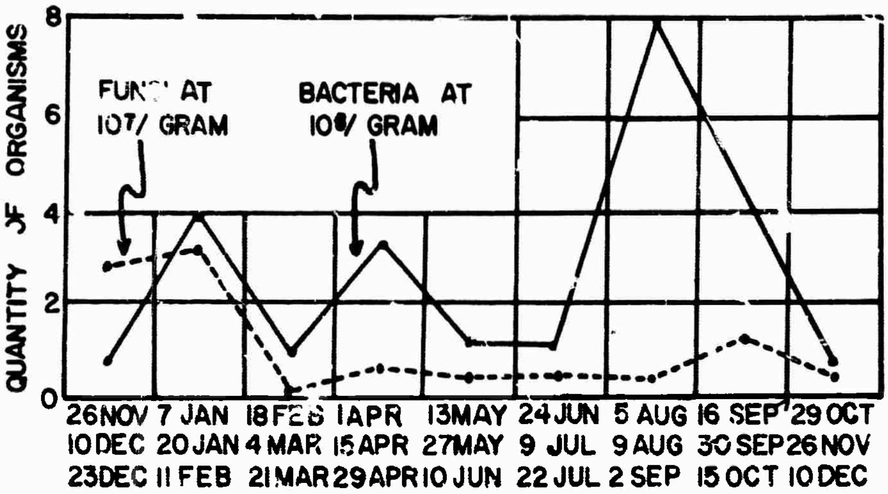

FIGURE VI-4. ANNUAL VARIATION OF FUNGAL AND BACTERIAL CONTENT OF GROUND LITTER

PART VII. MICROBIOLOGY AND CHEMISTRY OF THE ATMOSPHERE

During the reporting period observations were made on the following: deposition of microorganisms on prepared surfaces, distribution of airborne microorganisms, microorganisms in soils, particulate matter in the atmosphere, atmospheric chemistry, and the microbiology of rainwater. Routine observations were made in most of these lines of investigation. Observations of condensation nuclei which were carried out in a limited manner in the preceding period, were discontinued due to equipment troubles.

The reports on airborne and surface microorganisms and on microorganisms in soils which follow were derived from papers given at the 1967 meetings of the Society for Industrial Microbiology by the principal authors. This is the first time that results of the microorganisms in soils work have been given in the semiannual reports. Atmospheric chemistry and the microbiology of rainwater work will be described in later semiannual reports when data for sufficiently long periods are available for meaningful analyses.

Airborne and Surface Deposited Microorganisms*

Introduction

Observations of both the distribution of airborne microorganisms and the deposition of microorganisms on prepared surfaces continued during the reporting period. The study presented here is based on data collected at the Albrook and Chiva Chiva sites during the period of July 1966 through December 1966, and concerns relationships between microorganisms found in air and those which were collected on exposed surfaces. The study attempts to answer the following basic questions: (a) how many and what kind of living microbial forms inhabit the two environments? (b) how do seasonal and diurnal factors, and height above ground affect the numbers and kinds of microbial forms? and (c) is there a direct relationship between the airborne population and the extent of microbial contamination on exposed surfaces?

The environments of the humid tropics are optimum or near optimum for microbial life. Temperature is always warm, never cold, with prevailing levels varying only a few degrees from an average of 80 to 85 F. Moisture is abundant and relative humidity is high. Dying plants continuously provide a supply of organic matter from which microorganisms derive energy. Leaves of living plants provide much of the surface upon which microbial forms grow as well as shade for protection against direct sunlight. In this nearly ideal environment biotic activity is intense; and microbial populations, particularly of degradative and parasitic species, are higher than those found elsewhere in the world.

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* This section was prepared by Dr. Robert S. Hutton, Biological Scientist, and Mr. George Gauger, Microbiologist.

Gregory[11] wrote that "data from...surface traps have been interpreted on the tacit assumption that the relation between the number of particles suspended in the air flowing over the surface and the number deposited on the surface is known". He found in wind tunnel experiments, however, that spore concentration is only one factor in determining deposition, and that particle size, wind speed, and the dimensions and orientation of the trap surface can exert an overriding effect on deposition. Since exposed surfaces in the tropical environment are subject to infestation and subsequent deterioration by microbial forms, the environmental factors which influence the manner in which contamination takes place could have practical importance. For example, substantial monetary losses have resulted and are continuing to result from biodeterioration of military materiel in humid tropical environments.

Data Collection Methods

Methods used were described in previous reports; briefly, they were as follows. Airborne microorganisms were collected by direct air filtration on type HA, 47 mm., gridded, Millipore membrane filters. After sampling, the filters were placed on plates of sterile carrot agar and incubated at room temperature. Numbers of microorganisms were recorded at the time of appearance of maximum numbers of colonies, usually 72 hours. Fungi to be identified were isolated at the time that numbers of colonies were counted. Colonies exhibiting characteristics of fungi were transferred to other sterile plates containing Czapek's or Saboraud's agar where they were allowed to grow to maturity. The direct air filtration method was selected after comparison of this method with the generally more favored method of liquid scrubbing using the Rosebury-Henderson capillary impinger [12]. Direct filtration yielded consistently higher numbers of microorganisms per unit volume of air sampled. Differences between samples taken at the same time were also less when sampling was accomplished by direct filtration. No attempt was made to determine why this method yielded higher numbers of viable microorganisms.

The per-unit-volume numbers of bacteria and fungi in the atmosphere were determined each six hours of the day for the first five working days (Monday through Friday) of each month. The period of sampling was five minutes. For technical and meteorological reasons, sampling could not be carried out at exactly the same time each day, however, times of sampling varied only slightly from 0300, 0900, 1500, and 2100 and were assumed to be representative of the 0-6, 6-12, 12-18, and 18-24 hour periods each day.

Numbers of bacteria and fungi falling on surfaces were determined by exposing nutrient-free agar plates to the atmosphere for one hour. Plates were exposed each quarter of the day (approximately 0300, 0900, 1500, 2100) each Thursday of every week. Data collection began in July 1966 and extended through December 1966. Gregory [13] described the gravity Petri dish method of collecting microorganisms. Petri plates containing non-nutrient agar were exposed inside open-ended sterile fiberglass tubes five inches in diameter and sixteen inches long. The tubes served to shield the

plates from insect and plant debris as well as rain. Tube-plate sets were exposed in pairs, one tube being oriented north-south, the other east-west. Over the period of observation, the numbers of both bacteria and fungi collected in the N-S and in the E-W tubes were practically equal. Based on this observation, the overall effect of wind direction was assumed to be negligible and the sets of tubes were regarded as duplicates. After sampling, the plates were brought to the laboratory and overlaid with sterile nutrient-containing pads. Fungi and bacteria growing on plates fortified with Czapek's and nutrient broth respectively were counted and numbers deposited per 100-square cm surface were calculated.

Results

Observations were made in terms of the influence of site, height above ground, time of day, and month. The main effects produced by these factors on the number of fungal spores found in the air are summarized in Table VII-1. Significant differences were determined for airborne spores of fungi associated with site, height, time of day (hours), and month of year. Similar significance was associated with time of day and month of year for fungal spores deposited on surfaces. A quotient was derived by dividing deposited spores by airborne spores. In the overall sampling, the quotient 0.32 indicates a relative rate of fungal spore deposition per unit of time (1 hour). Site and height showed minor effect on this relationship. On the other hand, this quotient varied substantially with time of day and month of year. Relatively more spores were deposited during the afternoon hours and in the months of July and October. Conversely, fewer spores were deposited in the early morning hours and during the months of November and December.

Similar effects were observed with bacterial cells in the air and those deposited on surfaces (see Table VII-2). Substantial differences were found for bacterial cells associated with height over ground, time of day (hours), and month of year. The numbers of bacterial cells deposited on surfaces as well as those found in the air also varied with height, time of day, and month of day. Site appeared to have little effect on the airborne and deposited bacterial cells. The relative rate of deposition for bacterial cells is 0.76, more than twice that derived for fungal spores. Relatively greater numbers of bacterial cells were deposited from noon to midnight and during the months of August and October, while fewer numbers were deposited from midnight to sunrise and in the months of November and December.

These effects were re-examined to determine their influence on the occurrence and distribution of fungi. Fungi were most numerous during the month of July, decreased abruptly in August, increased, somewhat irregularly, during the following months (Table VII-3). Representatives of each genus differed individually throughout the six-month period. Representatives of the genera Fusarium, Gliocladium, Penicillium, Hormodendrum, Cephalosporium, and Oidium comprised nearly 80 percent of the isolates found in the air.

TABLE VII-1. QUANTITATIVE EFFECTS ON AIRBORNE AND SURFACE-DEPOSITED FUNGAL SPORES RELATED TO SITE, HEIGHT OVER GROUND, TIME OF DAY, AND MONTH.

Type of Sample	Mean Numbers in 100 L of Air	Mean Numbers Falling on 100 CM^2 in 1 Hr.	Ratio: Deposited/ Airborne
ALL SAMPLES	84	27	.32
SITE	**		
Forested	79	27	.34
Clear	90	27	.30
HEIGHT OVER GROUND	**		
Surface	92	27	.29
37 m	76	27	.36
TIME, HOURS	**	**	
0-6	140	31	.22
6-12	80	25	.31
12-18	42	23	.55
18-24	76	26	.34
MONTH (1966)	**	**	
July	73	31	.42
August	83	29	.35
September	94	32	.34
October	73	45	.61
November	73	11	.15
December	110	11	.10

NOTE: Values below asterisks differ from mean of all samples at the 1% level (*), or the 5% level (**).

TABLE VII-2. QUANTITATIVE EFFECTS ON AIRBORNE AND SURFACE-DEPOSITED BACTERIA RELATED TO SITE, HEIGHT OVER GROUND, TIME OF DAY, AND MONTH.

Type of Sample	Mean Numbers in 100 L of Air	Mean Numbers Deposited on a 100 CM^2 in 1 Hr.	Ratio: Deposited/ Airborne
ALL SAMPLES	25	19	.76
SITE			
Forested	25	19	.76
Clear	25	19	.76
HEIGHT OVER GROUND	**	*	
Surface	28	20	.71
37 m	21	18	.85
TIME, HOURS	**	**	
0-6	46	23	.50
6-12	21	16	.76
12-18	16	21	1.31
18-24	16	15	.93
MONTH (1966)	*	**	
July	23	20	.86
August	22	39	1.77
September	22	17	.77
October	26	24	.92
November	24	8	.33
December	30	7	.23

NOTE: Values below asterisks differ from mean of all samples at the 1% level (*), or the 5% level (**).

TABLE VII-3. RELATIVE FREQUENCY OF 15 GENERA OF AIRBORNE FUNGI DURING A SIX-MONTH EXAMINATION PERIOD.

ORGANISM	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
Fusarium	32	39	82	41	100	97	391
Gliocladium	17	11	22	19	59	68	196
Penicillium	60	16	38	33	25	23	195
Hormodendrum	76	2	21	7	3	58	167
Cephalosporium	44	22	23	15	6	45	155
Oidium	45	21	23	36	5	19	149
Streptomyces	0	1	30	31	34	0	96
Aspergillus	37	16	2	12	4	4	75
Spicaria	27	13	8	4	5	0	57
Curvularia	5	10	14	12	10	2	53
Trichoderma	11	2	0	8	4	18	43
Rhinotrichum	1	2	2	12	6	8	31
Nigrospora	0	0	4	1	3	1	9
Monilia	2	0	0	0	0	0	2
Verticillium	1	2	1	0	1	0	5
TOTAL	358	157	270	231	265	343	

More fungi were found in the dark environment than in daylight (Table VII-4). Representatives of the genera Fusarium, Gliocladium, and Trichoderma, in particular, were more numerous during the hours of darkness. The dark-spored forms representing the genera Curvularia and Nigrospora appeared more abundantly in daylight hours.

Fungi isolated from the cleared and from the forested (shaded) sites paralleled the pattern observed for the daylight and dark conditions, in many instances. Isolates of Fusarium, Gliocladium, and Trichoderma were more abundant in the forested site than the cleared site (Table VII-5). Again, Curvularia spp. and Nigrospora sp. were encountered more frequently in the cleared site, which is more comparable to daylight, than in the forested site, which compares favorably to darkness.

Unexpectedly there was little effect in the numbers of fungal isolates associated with height above ground level (Table VII-6). The abundance of Fusarium spp. at the surface more than accounted for the total difference observed between the surface and 37 meters. Another unusual observation was that Nigrospora sp. was found only at the 37-meter level and was never detected at the surface. Additional differences were expected to account for the significance associated with heights in the first analysis (Table VII-1). In all other cases sufficient differences were expressed to add to the validity of the significance attributed to sites, time of day, and month.

Summary

The important finding is that the different conditions of time and position existing at the two locations produced significant variations un the microbial populations. Tables VII-1 and -2 show that the numbers of both fungi and bacteria within the air and deposited on surfaces varied substantially from place to place, hour to hour, month to month and, even with difference in height above ground. These results become even more interesting if it is recognized that those [illegible]ps were significant in spite of substantial variation between parallel samples. Continued inspection of the data projects the supposition that the basic variables which influence the presence of microbial forms in the environment are not adequately defined in simple terms of site, time, height over ground, and season. Instead, the data tend to confirm Gregory's contention that specific elements of the micrometeorological environment such as temperature, wind speed, relative and absolute humidity, as well as light, may, in combination exert overriding influences. Furthermore there is some evidence, in the form of the variation between calculated relative rates of deposition of airborne forms on surfaces, that rates of deposition also are related to these environmental factors. Data on most of the environmental factors were collected in parallel with the sampling of microorganisms and an attempt will be made to determine their influences.

Taken collectively, the results of observations on representatives of genera of fungi encountered in air (Tables VII-3 through -6) confirm the

TABLE VII-4. RELATIVE FREQUENCY OF 15 GENERA OF AIRBORNE FUNGI DURING DAYLIGHT AND DARK HOURS OVER A SIX-MONTH PERIOD (1966)

ORGANISM	DAYLIGHT	DARK	TOTAL
Fusarium	123	268	391
Gliocladium	55	141	196
Penicillium	103	92	195
Hormodendrum	84	83	167
Cephalosporium	82	73	155
Oidium	77	72	149
Streptomyces	37	59	96
Aspergillus	39	36	75
Spicaria	22	35	57
Curvularia	47	6	53
Trichoderma	6	37	43
Rhinotrichum	19	12	31
Nigrospora	9	0	9
Verticillium	3	2	5
Monilia	1	1	1
TOTAL	707	917	

TABLE VII-5. RELATIVE FREQUENCY OF 15 GENERA OF AIRBORNE FUNGI AT CLEARED AND FORESTED SITES DURING A SIX-MONTH PERIOD (1966)

ORGANISM	CLEARED	FORESTED	TOTAL
Fusarium	184	207	391
Gliocladium	74	122	196
Penicillium	85	110	195
Hormodendrum	91	76	167
Cephalosporium	68	87	155
Oidium	66	83	149
Streptomyces	62	34	96
Aspergillus	28	47	75
Spicaria	34	23	57
Curvularia	37	16	53
Trichoderma	9	34	43
Rhinotrichum	25	6	31
Nigrospora	9	0	9
Verticillium	3	2	5
Monilia	2	0	2
TOTAL	777	847	

TABLE VII-6. RELATIVE FREQUENCY OF 15 GENERA OF AIRBORNE FUNGI FOUND AT SURFACE AND 37 M ABOVE GROUND DURING A SIX-MONTH PERIOD (1966)

ORGANISM	SURFACE	37 METERS	TOTAL
Fusarium	236	155	391
Gliocladium	97	99	196
Penicillium	98	97	195
Hormodendrum	80	87	167
Cephalosporium	77	78	155
Oidium	71	78	149
Streptomyces	50	46	96
Aspergillus	37	38	75
Spicaria	21	36	57
Curvularia	25	28	53
Trichoderma	28	15	43
Rhinotrichum	10	21	31
Nigrospora	0	9	9
Verticillium	4	1	5
Monilia	2	0	2
TOTAL	836	788	

observations on the effects just described. Examination of the effects of time, light, location, and height on each of the genera of fungi revealed that not all individuals react to these variables in the same way. For example, some fungi appear more abundantly in the light, while others were more prevalent in the dark. The ultimate desire to define the tropical microbial environment will require studies of interactions between elements of the environment and each microbial form within the milieu of the dynamic state of the microbial community.

Even at the present time, patterns of occurrence of microorganisms are beginning to emerge. The two most common forms in the soil, namely Fusarium spp. and Penicillium spp. are listed first and third respectively, in order of frequency of appearance in air.* On the other hand, Gliocladium spp., which rated second in order of frequency of appearance in air, was relatively infrequent in samples of soil, while Trichoderma spp., the third most numerous soil form, appeared in the group seen least frequently in the air. The maximum rate of fungus deposition for October (Table VII-1) coincides with the highest incidence of soil fungi observed.

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* See section "Microbial Inhabitants of a Tropical Semideciduous Forest Soil in the Canal Zone", which follows.

Microbial Inhabitants of Soil in a Tropical Semideciduous Forest*

Introduction

Soil is an ever-changing site of biological activity which influences the plant and animal populations that it supports as well as providing a primary reservoir for microorganisms. Determinations of numbers per gram of soil, as well as the isolation and description of microorganisms that are associated with soil, are quite common. An understanding of the actual activities of these organisms in the soil environment requires further experimentation and evaluation.

An organism becomes ecologically important when it is metabolically active, capable of colonizing the available substrates, and present in sufficient numbers to materially alter the environment. Soil fungi have been, in recent years, studied more extensively than other types of microbes. Within microbial populations, fungi are generally accompanied by other organisms which also contribute to the overall aspect of the microhabitat. The existence of a specific organism in a given locality, e.g., a warm, humid environment, usually develops through the ability of that organism to grow and multiply on the available substrates or to be transmitted to the locality from elsewhere. Information included herein is primarily involved with the microorganisms that grow and multiply on the organic substrates of the soil in the Canal Zone.

Previous Investigations

A few investigations of the soil fungi of Panama and the Canal Zone have been conducted. Farrow[14] isolated 135 species representing 73 genera from soil samples obtained from six major areas in the Canal Zone and Costa Rica. Goos[15] isolated and identified 47 species of fungi representing 33 genera from soils and banana root samples obtained from Costa Rica and Panama. In most instances direct plating of soils onto agar surfaces, or dilution plate techniques were employed. These techniques do not allow for accuracy in determination of population changes.

Numerous investigators (Sadasivan [16]; Walker[17]; Sorgel[18]; Staffeldt[19]; and Calderon and Staffeldt[20]) have employed the trap burial technique to determine the general succession of different types of fungi that will colonize the buried traps. Garrett[21] stated that once an organic segment is added to the soil it is invaded by those species that are both "eligible" and in the immediate vicinity at the moment the

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* This section was prepared by Dr. Eugene E. Staffeldt, professor of Biology, New Mexico State University, who serves as a consultant for the Environmental Data Base project. Work reported was carried out at New Mexico State University by Dr. Staffeldt and student assistants and was based on a period of sampling (1965-1966) prior to the period covered by this semiannual report.

substrate becomes available for colonization. He also reported that the successful saprophytic organisms possess (a) rapid growth rate of hyphae and germination of spores, (b) broad enzyme-producing systems, (c) ability to produce toxins and/or (d) tolerance of toxins produced by other microorganisms. The composition of a micro-community at a given time would be dependent upon the many physical, chemical and biological aspects of the soil habitat.

Data Collection and Analysis

Soil samples were obtained on a monthly basis, from May 1965 through April 1966, from Tropic Test Center personnel. These samples were collected during the third week of each month from a 25 X 45-foot plot at the Albrook Forest site, that had previously been sectioned for sampling on a randomized basis. A cylinder of soil, 2½ inches in diameter and 1 inch thick was removed and represented the 0- to 3-, 3- to 6-, 6- to 12-, 12- to 15-, 15- to 18-inch layers. Three complete cores were removed each month. Following removal each cylinder was individually wrapped in aluminum foil and sealed in paraffin before shipping. Upon arrival in the United States, the soil samples were placed in a refrigerator until the experimentation commenced.

The 0- to 3- and 3- to 6-inch samples of each soil core were opened, the central areas of each were aseptically moved to a sterile, covered ... and thoroughly mixed. This soil was then placed as a layer over the bottom of a sterile petri dish. Sterile, unbroken alfalfa straws were placed on the soil surface, and additional soil was added to completely bury the stems. Three straws were removed from each sample after 2, 4, 8, 16, and 32 days of burial. Following removal, each stem was washed in tap water, rinsed five times in sterile distilled water and placed between sterile paper towels that absorbed the excess water. The ends of each stem were aseptically removed, and the remainder was cut into three equal segments. These pieces were then placed on the surface of carrot agar contained in petri dishes. Fungal growth from the plant stems and reproduction occurring on the stems were observed and recorded over a three-week period. Transfers were made to agar slants for identifications of some organisms and verifications of others.

In addition to the above, individual samples of soil were employed in dilution studies. Standard bacteriological dilution techniques were utilized. Nutrient agar was used for the enumeration of aerobic bacteria while Brewer's anaerobic agar, Czapek's agar and Sabouraud's agar were employed to determine quantities of anaerobic bacteria, fungi, and yeasts and similar forms, respectively. Adequate controls were maintained. All plates were maintained at ambient temperature, approximately 30 C. The plates containing Brewer's agar were placed in vacuum chambers, evacuated and a nitrogen atmosphere was introduced. Colony counts were obtained from the plates at 24-hour intervals for three days. A plate was considered valid when it contained more than 30 and less than 300 colonies. Likewise the counts on the valid plates had to be substantiated by the other dilutions

employed. Three replications of each soil sample were included in these studies.

Results

Soil dilution studies were conducted to obtain a comparison of the relative abundance of the various types of organisms that could be encountered. The relative density of bacteria per g .. of soil exceeded that of the fungi throughout the 12-month examination period (Figure VII-1). Major peaks were observed for bacteria during the months of August and October while a third, and lower, peak was expressed in the month of April. Fungi were generally fewer in number than bacteria, and the only predominant peak occurred during the month of October. Low fungal counts were made during May, November, December, January, and April. A more critical examination of the bacterial densities revealed that the high numbers of bacteria in August and April were primarily anaerobic forms while those in October were aerobic forms (Figure VII-2). Both aerobic and anaerobic bacteria were apparent throughout the wet season (approximately 80 inches of rainfall during the months of May through December) and the dry season (almost no measurable rainfall during the months of January through April).

The activities of fungi were more closely examined as they colonized buried, sterile, plant stems and grew out of these after 2, 4, 8, 16, and 32 days burial. Monthly totals of three of the most prevalent genera of fungi invading and growing from straws are summarized in Figure VII-3. Fusarium spp. appeared most frequently and were found on 80 percent or more of the stems during every month but February. Representatives of this genus were observed more consistently than any of the other fungi recorded. On the other hand Fusarium spp. were not observed regularly or abundantly in soil dilution studies. Similarly, Penicillium spp. were observed less frequently than Trichoderma spp.. During nine months of the year these organisms (Penicillium) were found on 50 percent or more of the stems and were most abundant in February. The pattern of appearance suggested a bimonthly increase of these organisms. Penicillium spp. were not as abundant as either Fusarium spp. or Trichoderma spp. in the stem burial study but accounted for almost 100 percent of the organisms observed during October in the soil dilution experiment. Trichoderma spp. produced the most erratic expression of the three genera of organisms observed. Representatives of this genus were found on 50 percent or more of the stems during six months of the examination period. During two months of the year these organisms were not observed on any of the stems.

Appearances of each of the above organisms were re-examined on the basis of the five stem removals during each month. There were no consistent colonization patterns expressed that would indicate that these organisms occur early and slowly disappear or that they colonize the stem after the establishment of another organism. The occurrence of Fusarium spp. usually varied between 80 and 100 percent with the exception found in February. During this month 83 percent of the stems possessed colonies of

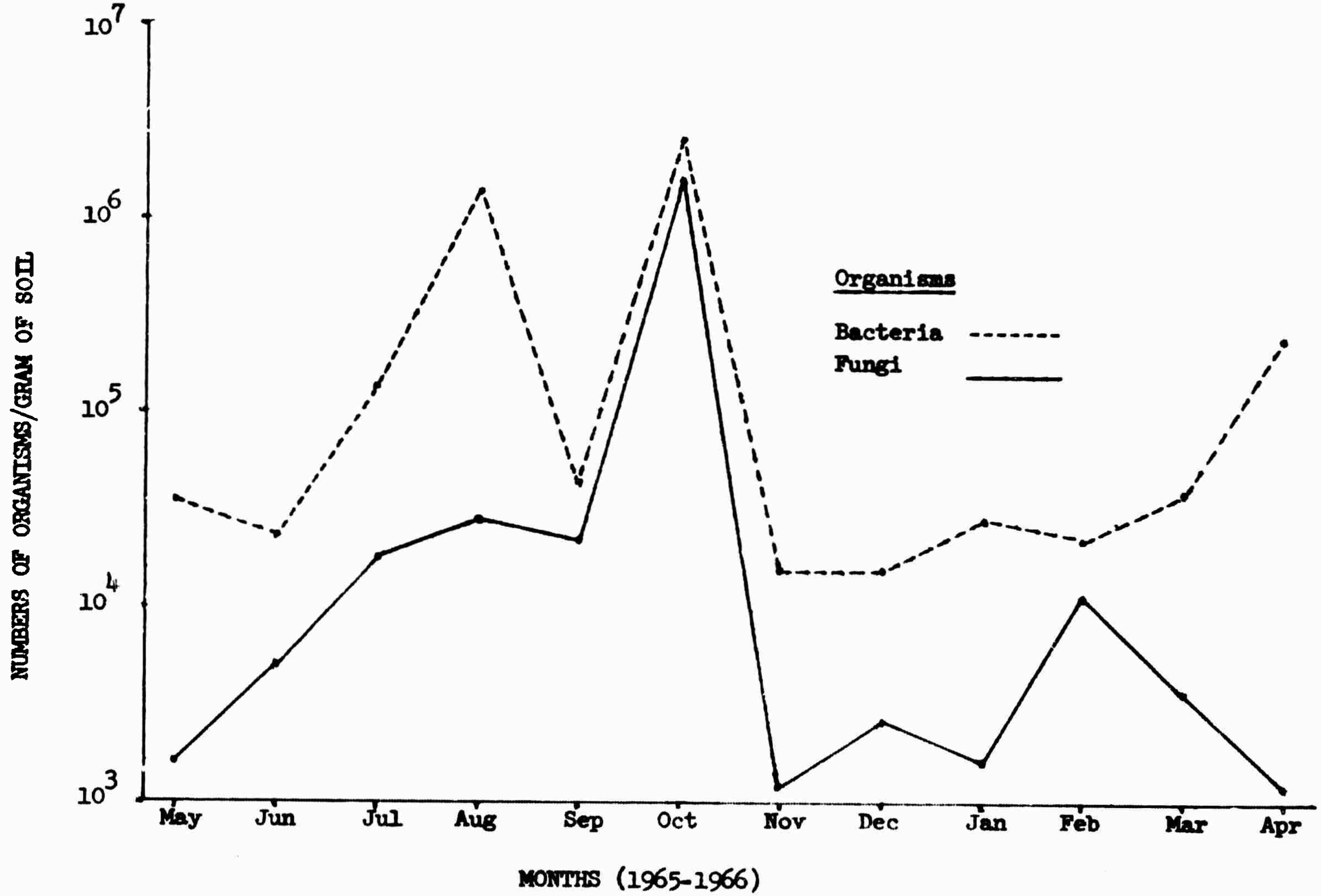

FIGURE VII-1. RELATIVE FREQUENCY OF BACTERIA AND FUNGI PER GRAM OF SOIL OVER A ONE-YEAR PERIOD.

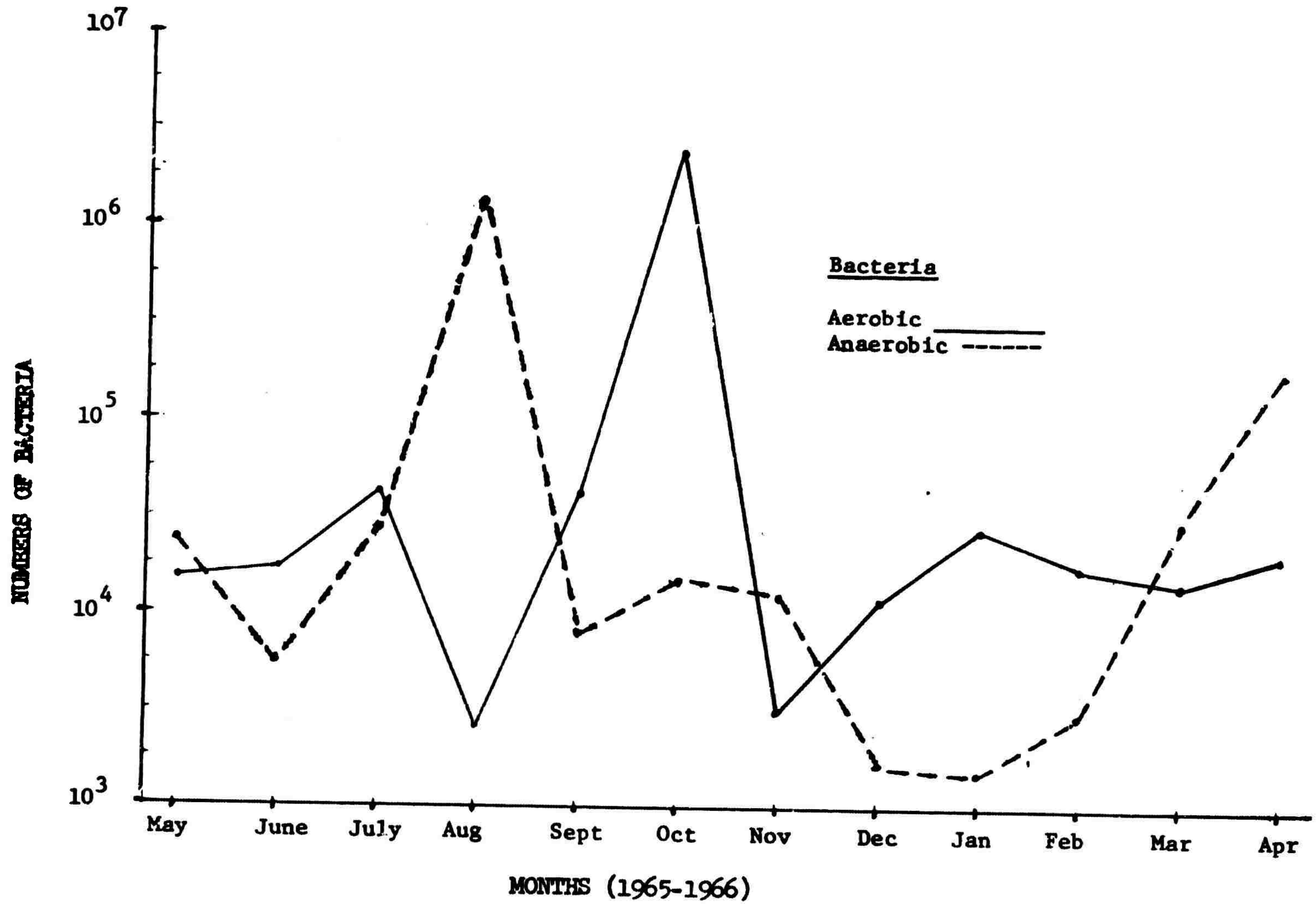

FIGURE VII-2. RELATIVE FREQUENCY OF AEROBIC AND ANAEROBIC BACTERIA PER GRAM OF SOIL OVER A ONE-YEAR PERIOD.

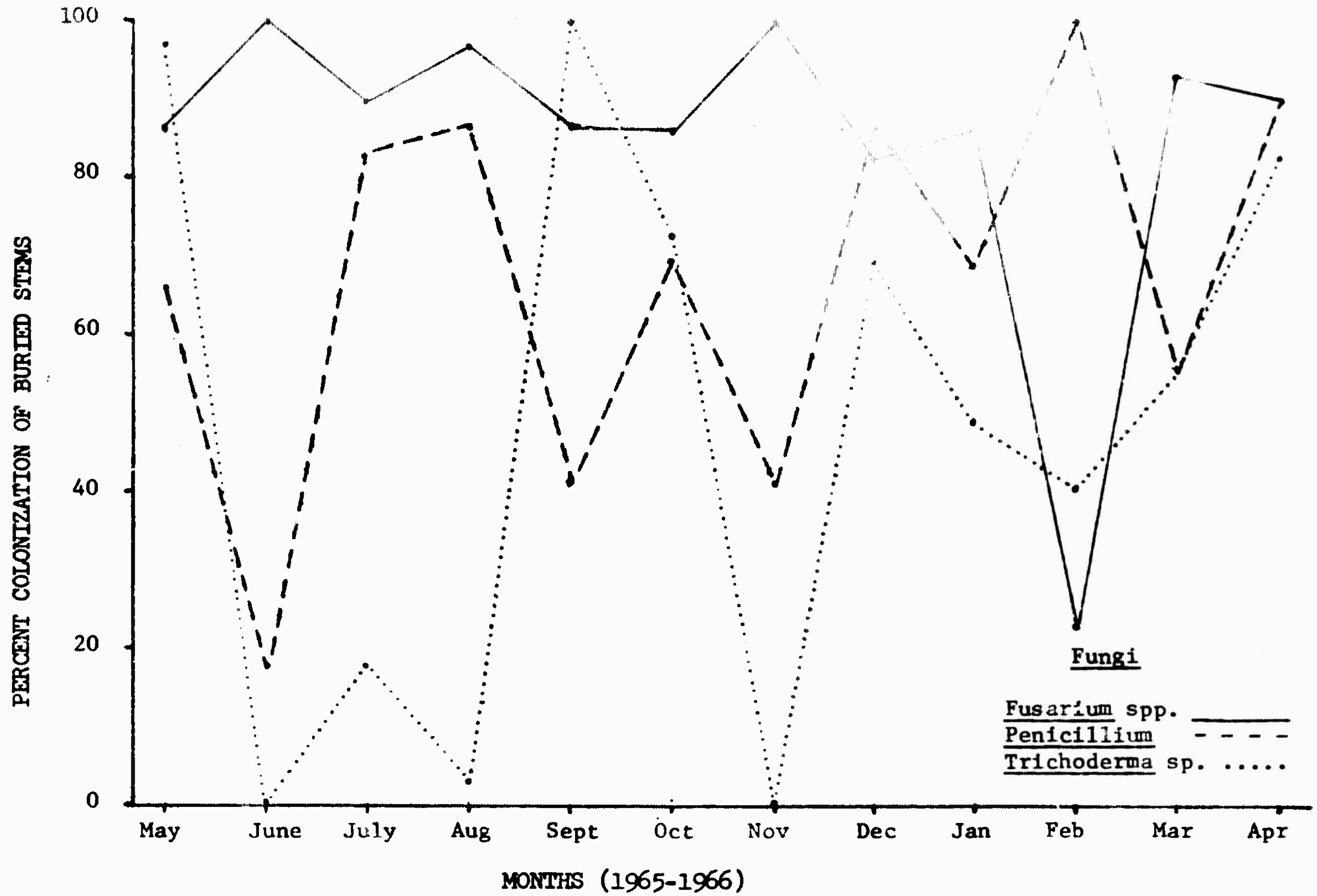

FIGURE VII-3. PERCENT COLONIZATION OF BURIED STEMS BY THREE GENERA OF FUNGI OVER A ONE-YEAR PERIOD.

these organisms after two days, and no *Fusarium* colonies were found after 4, 8, 16, and 32 days. Variations between the end of one month and the beginning of the next month were usually never greater than the variations that occurred between examination days within the month. Greater variations were found in the colonization and expression patterns of *Penicillium* spp. and *Trichoderma* spp. Total suppression of *Penicillium* spp. occurred during the month of June. During ten months of the year these organisms were found on 100 percent of the stems on one of the examination dates of that month. This expression of high numbers was usually followed by a fairly rapid decline. In this respect, *Trichoderma* spp. were more consistent. These organisms were found either relatively abundantly or few in numbers throughout the month. These three genera of organisms did not appear to be drastically affected by readily apparent seasonal trends.

Other fungi colonized the buried stems but their colonization and appearance patterns have not been evaluated to date. The most common, to least common, fungi include representatives of the genera *Phoma*, *Hyalopus*, *Streptomyces*, *Aspergillus*, *Masoniella*, *Myrothecium*, *Stachybotrys*, *Alternaria*, *Pythium*, *Xylaria*, *Cunninghamella*, *Hormodendrum*, *Gliocladium*, *Saksenaea*, *Monilia*, *Curvularia*, *Mucor*, *Pyrenochaeta*, *Nigrospora*, *Volutella*, *Chaetomium*, *Helminthosporium*, *Sphaeronema*, and *Ophiostoma*.

Bacteria were found growing in small colonies from the straws, but did not influence the growth and reproduction of the fungi. Nematodes were not observed on any of the plated stems.

Many interesting facts developed during the course of this investigation. The density of bacteria per gram of soil was relatively low throughout the 12-month examination period. This was emphasized by the occurrence of 10^4 to 10^6 total bacterial cells per gram of soil compared to the 10^9 cells per gram of agricultural soil as reported by Burges[22]. Brock [23] reported that a single species becomes ecologically important only when the population density reaches 10^6 cells per ml. Assuming this statement to be correct, the bacteria could have influenced this tropical soil microenvironment only during August and October, 1965, if the majority of the bacteria represented a single species. Additional dilution plates have been examined for the period August 1966 - May 1967, and all but two months yield bacterial densities of less than 10^6 cells per gram of soil. Presently the handling and shipping techniques are being investigated to insure that population densities are not being reduced during these procedures. If data reported herein continue to be collected and reveal similar bacterial soil concentrations it might be assumed that bacteria are less important than previously suspected in tropical soil environments.

Another aspect that requires additional investigation is the relatively high number of aerobic bacteria that appeared in October, within the prolonged rainy season. Also, the increase in number of anaerobic bacteria during March and April, the end of the dry season, requires further examination.

In this semideciduous forest the most extensive amount of litter fall occurs during the dry season (January through April). This increased addition of organic substrate did not change the soil microbial densities as had been expected in the dilution plate techniques. During the straw burial study, however, the soil samples collected in April produced the greatest variety and number of organisms.

The high fungal population expressed on dilution plates during the month of October were identified as Penicillium spp.. This organism grew equally well under aerobic and anaerobic conditions. In addition to growing in a nitrogen atmosphere which was passed through three bottles of pyrogallic acid, this organism grew well when the anaerobic containers were evacuated and maintained at -24 psi.

Three genera of fungi were most prevalent during the stem burial studies. Fusarium spp. were observed on 85 percent of the stems while Penicillium spp. and Trichoderma spp. were found on 67 and 49 percent of the traps, respectively. These soil inhabitants could be referred to as dominant organisms (Brock[23]) more easily than they could be referred to as primary invaders (Garrett[21]). The colonization patterns established within individual monthly examinations were not sufficiently consistent to enable one to predict the relative numbers of a specific organism. There was indication that possibly the metabolic wastes inhibited the further activity of certain organisms. Representatives of the other 24 genera of fungi were less prevalent and were considered as associated or incidental fungi. Within these organisms it was easier to detect primary and secondary types as well as late colonizers. Brock[23] stated that an analysis of a large system is difficult and often baffling, and this investigation was no exception. Many small, simple experiments defining one variable will have to be conducted before an understanding of the gross changes can be reached.

Particulate Matter*

Introduction

Air contamination has long been recognized as a significant cause of damage to materiel in urban areas. Stern [24] emphasizes the effect of airborne particulate matter in deterioration caused by exposure to polluted atmospheres. He points out that deposited particulate matter markedly accelerates the corrosion of metals, and he estimates that corrosion and deterioration attributable to air pollution involve yearly costs of more than a billion dollars. The majority of reports citing deterioration of materials caused by air pollutants deal with observations made in and around cities. Deterioration of material in tropical regions, on the other hand, is seldom associated with contaminated atmosphere. Instead, reports on tropical deterioration cite effects of moisture, high temperature, and microbial action as the main factors responsible for deterioration and corrosion. There is a paucity of reports on the particulate content of tropical atmospheres, but air in such regions is usually assumed to be relatively free from pollutants because of general lack of major urban influence and the fact that it is washed frequently by torrential rains.

The previous Semiannual Report[1] contains results of air sampling for detection of particulates too small to reflect white light. This work was done because we too assumed that the major source of atmospheric pollution in the tropics would be from the gradual condensation of large molecules of plant volatiles to form freezing nuclei, with the subsequent agglomeration of these to form larger particles. Results reported in the above cited report (Condensation Nuclei and Particulate Matter) confirmed the existence of a high concentration of particulate matter in the submicron region, and also revealed the presence of a high concentration of large particulates.

No new work on sampling for sub-micron size particulate matter is to be reported here. Instead this report is limited to a presentation of data from extended and continuous observations of larger atmospheric particles. Investigation of particles large enough to be seen should include microscopic examination to determine structure and composition. For example, particulates may be fibrous; and they may consist of minerals, industrial wastes, or biological substances. Particulates should also be subjected to chemical analysis, if appropriate. Neither manpower nor equipment was available for microscopic examination or chemical analysis during this period. Instead air was sampled approximately every two hours to determine the amount of contaminant present and the samples collected were retained for eventual future chemical analysis.

Data Collection and Analytical Methods

A modified Gelman paper tape sampler, shown in Figure VII-4 was

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* This section has been prepared by Mr. George W. Gauger, Microbiologist, and Dr. Robert S. Hutton, Biological Scientist.

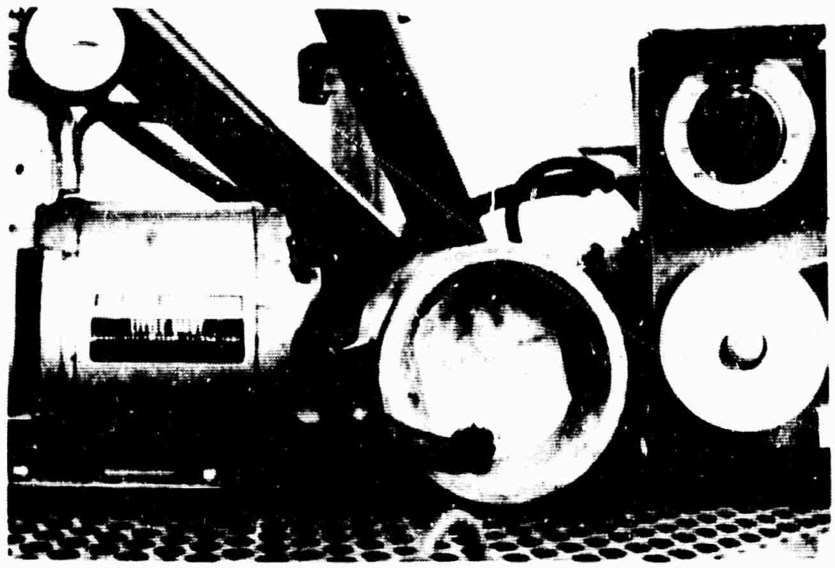

FIGURE VII-4. PAPER TAPE SAMPLER, SILICAGEL CARTRIDGE, AND VACUUM PUMP

located 46 meters above ground on the tower at the Chiva Chiva open site. Air was sampled continuously. Each sample of air collected over a two hour period was drawn by reduced pressure through a Whatman # 41 filter paper. The removal of particulates was not complete, but about 90 percent of the particles one micron or larger were deposited on the paper. The filter paper strip is fed automatically from the tape dispenser through the sampling head and along the tape guide and wound on a take-up spool for analysis and storage. At the end of each 24-hour period the filter paper strip is dated and returned to the laboratory for optical density measurements. The measurements are made with the Gelman Paper Densitometer shown in Figure VII-5. Its function is to measure the difference in light transmittal through the paper tape between a clean and sampled spot. This is done by placing a light source on one side of the paper tape and measuring the current generated by a photoelectric cell mounted on the other side of the tape. The amount of light transmitted through the paper strip is proportional to the concentration of particulate deposits and correspondingly affects the output of the photoelectric cell. The sampled paper tape is inserted into the densitometer and the optical density readings are recorded. Optical density readings are read arbitrarily as COH units (Coefficient of Haze).

Results and Conclusions

The data obtained beginning 1 April 1966 are graphically represented in Figure VII-6 which demonstrates that the highest number of COH units are recorded for the latter part of the dry season months, while a decreased number of COH units is recorded for samples taken during the wet season and early dry season months. The mean, maximum, and minimum COH units, with date and hour of occurrence, are recorded in Appendix D.

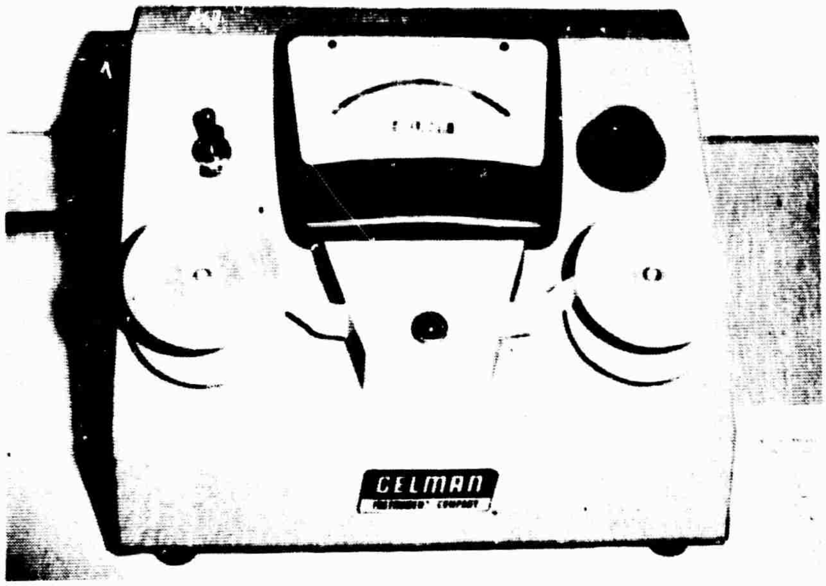

FIGURE VII-5. GELMAN PAPER DENSITOMETER

The values in the graph (Figure VII-6) below as well as those shown in the appendix are given as COH units per 1000 linear feet. This is an accepted standard; "linear feet" refers to a cylindrical column of air corresponding to the size of spot resulting from passage of the air through the paper tape.

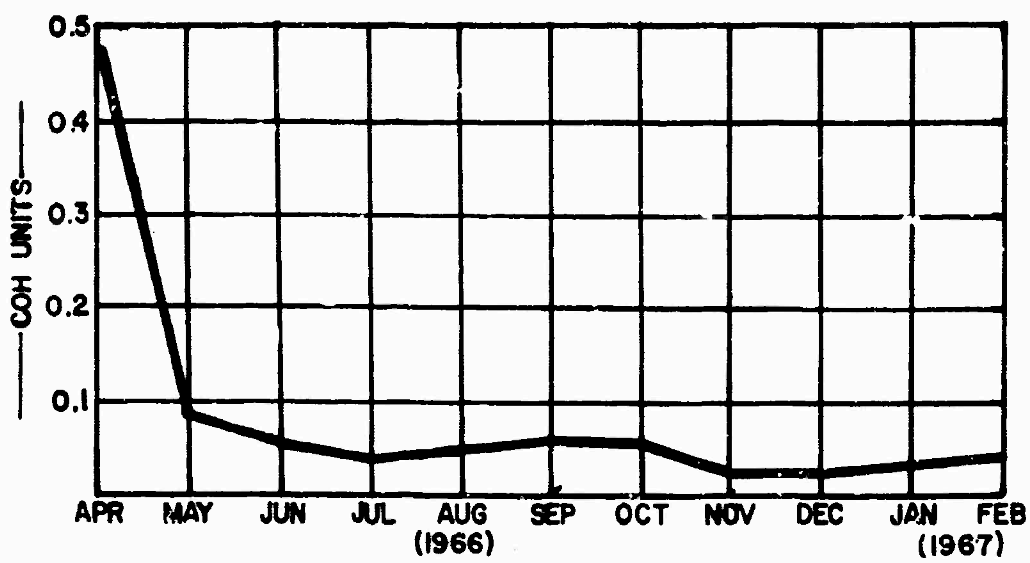

FIGURE VII-6. COH UNITS/1000 LINEAR FEET OF AIR SAMPLED AT CHIVA CHIVA SITE

Data obtained to date indicate that the highest COH values were recorded between 1400 and 1800 hours near the end of the dry season. Undoubtedly much of the increase in airborne particulate matter found at this time is from the extensive burning which goes on during this season, and unfortunately these data do little more than provide an index to the time of burning of grass and shrubs. This information may be useful in determining meteorological conditions which might favor or prevent the incidence of forest fires. The overloading of samples with smoke particles, however, completely precludes examination of the tapes for the presence of particulates originating from other sources. During times when particulate samplings are not influenced by smoke, the times for maximum and minimum values vary widely. Interpretation of the data will require both chemical analysis of the samples and correlation of maximum and minimum values in sampling with prevailing meteorological conditions.

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- APPENDIX A -

SOIL PROFILE DESCRIPTIONS AND SUMMARY TABLES OF PHYSICAL CHARACTERISTICS

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SOIL PROFILE DESCRIPTION
(Albrook Forest Site)

1. <u>Location</u>: Albrook Air Force Base, Dump road, approximate grid coordinates 17P-PV 662 964.

2. <u>Profile Description</u>:

Aoo Loose dry leaves, 3 to 5 centimeters thick.

Ao Partly decomposed forest litter from deciduous trees. 1 to 2 centimeters thick.

A_{11} 0 to 4 centimeters, very dark brown (10YR 2/2, moist) light clay with a fine to medium strong granular or fine weak subangular blocky structure; slightly hard when dry, friable when moist, sticky and slightly plastic when wet; roots plentiful; moderate to fairly high organic matter content; moderately permeable when undisturbed. 2 to 8 centimeters thick; gradual smooth lower boundary;

A_{12} 4 to 30 centimeters, very dark gray (10YR 3/1, moist) to very dark brown (10YR 2/2, moist) clay with a medium strong subangular blocky structure; hard when dry; slightly friable to firm when moist, sticky and plastic when wet; roots numerous to abundant; 20 to 30 centimeters thick; abrupt wavy lower boundary;

A_3 30 to 35 centimeters, very dark grayish brown (10YR 3/2, moist) to very dark brown (10YR 2/2, moist) clay with common, fine, and distinct yellowish brown and yellowish red (10YR 5/6 and 5YR 4/6) mottles with a structure, consistency, and root content similar to the A_{12} horizon above. 5 to 8 centimeters thick; abrupt smooth to wavy lower boundary;

B_{21} 35 to 47 centimeters, very dark grayish brown (10YR 3/2, moist) clay with a coarse strong subangular blocky structure, with many concretions of limonite and hematite and with mottles similar to the A_3 horizon above; slightly hard when dry, friable to slightly firm when moist, sticky and plastic when wet; roots numerous; 10 to 25 centimeters thick; gradual wavy lower boundary;

B_{22} 47 to 57 centimeters, very dark grayish brown (10YR 3/2, moist) clay similar in all respect to horizon B_{21} above, except for the more prominent mottling and concretions. 8 to 20 centimeters thick; gradual wavy lower boundary;

Albrook Forest Profile (Cont'd)

BC 57+ centimeters, very dark grayish brown matrix (10YR 3/2, moist) clay prominently mottled with many medium to coarse reddish and yellowish brown mottles, black, purple, yellowish brown and reddish brown ferrogionous concretions 5 to 10 millimeters in diameter; massive structure; hard when dry, friable when moist, very sticky and plastic when wet; roots few;
At 3 meters soil is heavily gleyed, olive-bluish-gray colors.

SOIL PRO ILE DESCRIPTION
(Chiva Chiva Site)

1. Location: Fort Clayton Army Reservation, Chiva Chiva antenna field, approximate grid coordinates 17P-PV- 562 979.

2. Profile Description:

Ao Loose and partly decomposed organic matter. 0.5 centimeters thick.

A_1 0 to 3.5 centimeters, dark brown (10YR 3/3, moist) silty clay loam to silty clay with many fine ferroginuous concretions and with a fine to medium strong subangular blocky structure; very hard ehen dry, firm when moiis, sticky and slightly plastic when wet; roots plentiful. Thin, generally not more than 5 centimeters thick; abrupt smooth lower boundary;

AB or B_1 3.5 to 11.5 centimeters, brown to dark brown (7.5YR 4/4, moist) silty clay with numerous reddish and yellowish ferroginous concretions and with a medium to coarse strong subangular blocky or fine moderate prismatic structure; very hard when dry, firm to slightly friable when moist, sticky and plastic when wet; roots plentiuul; 5 to 12 centimeters thick; abrupt wavy lower boundary;

B_2 11.5 to 40.0 centimeters, dark brown (10YR 3/3, moist) to dark yellowish brown (10YR 3/4, moist) clay with numerous fine and coarse iron concretions (red, yellow, black) some peds 3 or 4 millimeters in diameter, and with a coarse to very coarse strong blocky or medium moderate to strong prismatic structure; slightly hard hen dry, friable to slightly firm when moist, sticky and plastic when wet; roots/abundant; 15 to 30 centimeters thick; abrupt wavy lower boundary;

B_3 40.0 to 46.0 centimeters, dark yellowish brown (10YR 4/4, moist) clay with concretions similar to horizon above and with a medium strong subangular blocky structure; slightly hard when dry, friable to slightly firm when moist, sticky and plastic when wet; roots few. 3 to 10 centimeters thick; gradual wavy lower boundary;

BC 46.0 to 53.0 centimeters, same as the B_3 horizon except numerous, fine, clear yellowish (10YR 5/6) mottles and increasing amount of fine to medium reddish hematitic concretions. Gradual wavy lower boundary;

Chiva Chiva Profile (Cont'd)

C_1 53.0 to 64.0 centimeters, dark grayish brown (10YR 4/2, moist) clay with common fine distinct yellowish brown mottles and numerous medium to coarse ferromagnesian concretions; medium moderate subangular blocky structure slightly hard when dry, slightly friable when moist, sticky and plastic when wet; roots few to absent;

C_2 64.0 to 100.0+ centimeters, grayish brown matrix (10YR 5/2, moist) clay with many medium distinct yellowish brown mottles and numerous concretions coarser than those contained in the C_1 horizon above, massive structure; slightly hard when dry, friable when moist, sticky and plastic when wet; roots plactically absent;

SOIL PROFILE DESCRIPTION
(Albrook Satellite Site)

1. Location: Albrook Air Force Base, Dump road, approximate grid coordinates 17P-PV- 600 960.

2. Profile Description:

Aoo Loose leaves, 3 to 5 centimeters thick.

Ao Partly decomposed forest litter from deciduous trees. 1 to 2 centimeters thick.

A_{11} 0 to 2.5 centimeters, dark brown (7.5YR 3/2, moist) silty clay to clay with a medium strong subangular blocky structure; slightly hard when dry, friable to slightly firm when moist, slightly sticky and slightly plastic when wet; roots plentiful; moderate to fairly high organic matter content; moderately permeable when undisturbed. 1 to 6 centimeters thick; abrupt wavy lower boundary;.

A_{12} 2.5 to 7.5 centimeters, dark brown (7.5YR 3/2, moist) clay with a medium strong subangular blocky structure; hard when dry, slightly friable to firm when moist, sticky and slightly plastic when wet; roots numerous; 5 to 10 centimeters thick; abrupt wavy lower boundary;

A_3 7.5 to 12.0 centimeters, dark reddish brown (5YR 3/3, moist) clay with a medium strong subangular blocky structure; hard to very hard when dry, slightly friable to firm when moist, sticky and plastic when wet; roots numerous; 3 to 12 centimeters thick; clear wavy lower boundary;

B_1 12.0 to 19.0 centimeters, dark reddish brown (5YR 3/4, moist) clay with a medium strong subangular blocky structure; hard to very hard when dry, firm when moist, sticky and plastic when wet; roots numerous; 7 to 15 centimeters thick; gradual smooth lower boundary;

B_{21} 19.0 to 27.0 centimeters, dark reddish brown (5YR 3/4, moist) clay with a medium to coarse strong subangular blocky structure; hard when dry, friable to slightly firm when moist, sticky and plastic when wet; roots numerous; 9 to 25 centimeters thick; gradual smooth lower boundary;

Albrook Satellite Profile (Cont'd)

B_{22} 27.0 to 52.0 centimeters, dark reddish brown (5YR 3/4, moist) clay with few fine faint reddish and yellowish red mottles and with a medium moderate subangular blocky structure; hard when dry, friable when moist, very sticky and plastic when wet; roots numerous; 10 to 20 centimeters thick; gradual wavy lower boundary;

BC 52.0 to 133.0, dark greyish brown (10YR 4/2, moist) clay with common fine distinct reddish brown mottles and with a massive structure; hard when dry, very friable when moist, very sticky and plastic when wet; roots few;

C 133.0 to 200.0+ centimeters, same as above except slightly redder and with many medium and coarse prominent mottles of red, reddish brown, yellowish brown, and grayish brown.

SOIL PROFILE DESCRIPTION
(Fort Kobbe Satellite Site)

1. Location: Fort Kobbe Military Reservation, K1 road, approximate grid coordinates 17P-PV- 569 848.

2. Profile Description:

Aoo   Loose leaves, 2.5 to 3.0 centimeters thick.

Ao   Partly decomposed forest litter. Very thin, 3 to 5 millimeters thick.

A_{11} 0 to 12 centimeters, very dark brown (10YR 2/2, moist, to black (10YR 2/1, moist) clay with a coarse to very coarse strong subangular blocky or medium moderate prismatic structure; very hard when dry; very firm when moist, very sticky and very plastic when wet; roots plentiful; 10 to 16 centimeters thick; abrupt wavy lower boundary;

A_{12} 12 to 24 centimeters, black (10YR 2/1, moist) clay with a coarse to very coarse strong subangular blocky or medium moderate prismatic structure; very hard when dry; firm when moist, very sticky and very plastic when wet; roots abundant; 15 to 25 centimeters thick; clear wavy to irregular lower boundary;

B_{21} 24 to 40 centimeters, very dark gray (10YR 3.1, moist) clay with common fine distinct reddish brown and yellowish brown mottles together with many iron concretions 3 to 5 millimeters in diameter; very coarse strong blocky or medium strong prismatic structure; hard to very hard when dry, firm to slightly friable when moist, sticky and plastic when wet; roots numerous; 15 to 30 centimeters thick; gradual wavy to irregular lower boundary;

B_{22} 40 to 56 centimeters, similar to the B horizon above except common fine faint reddish and yellowish brown mottles and few small concretions; roots few; 7 to 30 centimeters thick; clear wavy to irregular lower boundary;

C   56 to 60+ centimeters, dark yellowish brown (10YR 3/4, moist) clay with few fine faint yellowish and grayish brown mottles and concretions; massive structure; hard when dry, firm to very slightly friable when moist,sticky and plastic when wet; roots few;

SOIL PROFILE DESCRIPTION
(Fort Sherman Satellite Site)

1. Location: Fort Sherman Military Reservation, S1 Road, approximate grid coordinates 17P-PA- 117 261.

2. Profile Description:

Aoo	Loose leaves, 3 to 4 centimeters thick.
Ao	Partly decomposed forest litter. 1 to 1.5 centimeters thick.
A_{11}	0 to 4.5 centimeters, dark reddish brown (5YR 3/4, moist) silty clay to clay with a medium moderate granular to fine weak subangular blocky structure; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; roots plentiful; very permeable when undisturbed; 2 to 10 centimeters thick; abrupt wavy lower boundary;
A_{12}	4.5 to 8.0 centimeters, similar to horizon A_{11} above except yellowish red (5YR 4/6, moist). 2 to 6 centimeters thick; clear wavy lower boundary;
A_{13}	8.0 to 14.0 centimeters, yellowish red (5YR 4/8, moist) silty clay with a medium moderate granular to fine weak subangular blocky structure; slightly hard when dry; friable when moist, sticky and plastic when wet; roots abundant; 5 to 12 centimeters thick; clear wavy lower boundary;
A_3	14.0 to 21.0 centimeters, yellowish red (5YR 4/6, moist) light clay with a medium strong subangular blocky structure; hard when dry, friable to slightly firm when moist, slighty plastic and sticky when wet; roots numerous; 4 to 10 centimeters thick; clear wavy lower boundary;
B_{21}	21.0 to 26.0 centimeters, red (2.5YR 4/8, moist) silty clay with a medium strong subangular blocky structure; hard when dry, friable to slightly firm when moist, sticky and slightly plastic when wet; roots numerous; 5 to 12 centimeters thick; clear wavy lower boundary;
B_{22}	26.0 to 44.0 centimeters, same as horizon B_{21} above except red (2.5YR 4/6, moist)roots few; gradual wavy lower boundary;
B_{23}	44.0 to 100.0+ centimeters, same as horizon B_{22} above except red (2.5YR 5/8, moist);

Soils Properties Summary
(Trafficability Layers)

Site	Soil Layer in.	U.S. Department of Agriculture Textural Classification	Mechanical Analysis Percent Gravel	Sand	Silt	Clay	Unified Soil Classification System Classification	Fines Percent	Atterberg Limits LL	PL	PI	Dry Density pcf	Soil Moisture Content, Percent Dry Weight, Atmosphere Tension 0.00	0.06	15.0	Specific Gravity
Albrook Forest	0-3	Clay	0	13	29	58	MH	87	85	49	36	55.7	81.2	70.4	33.0	2.62
	3-6	Clay	0	6	29	65	MH	96	70	44	26	62.6	69.1	59.1	28.0	2.67
	(0-6)	Clay	0	9	29	62	MH	92	78	36	32	59.2	75.2	64.8	30.0	2.64
	6-9	Clay	0	3	29	68	MH	97	65	36	29	64.0	68.0	58.4	27.7	2.69
	9-12	Clay	0	6	18	76	MH	94	71	36	35	65.2	63.3	54.8	27.2	2.70
	(6-12)	Clay	0	4	24	72	MH	96	68	36	32	64.6	65.6	[illegible]	27.4	2.70
	12-15	Clay	0	19	24	57	CH	86	65	30	35	67.6	61.0	54.2	28.0	2.64
	15-18	Clay	0	7	19	74	CH	93	70	32	38	69.6	57.2	52.1	28.4	2.55
	(12-18)	Clay	0	12	22	66	CH	90	68	31	37	68.6	59.1	53.2	28.2	2.60
Chiva Chiva	0-3	Clay	0	21	33	46	MH	79	68	48	20	54.5	81.6	79.7	26.1	2.49
	3-6	Clay	0	21	26	53	MH	73	60	44	16	61.8	65.8	23.7	23.7	2.54
	(0-6)	Clay	0	21	30	49	MH	76	64	46	18	58.2	73.7	71.6	24.9	2.52
	6-9	Clay	0	30	21	49	MH	66	60	40	20	63.4	62.5	60.9	22.0	2.54
	9-12	Clay	0	30	19	51	MH	65	56	37	19	69.5	54.9	53.3	20.4	2.56
	(6-12)	Clay	0	30	20	50	MH	66	58	38	20	66.4	58.7	57.1	21.2	2.55
	12-15	Clay	0	32	18	50	MH	64	55	37	18	68.5	57.4	55.6	20.0	2.60
	15-18	Clay	0	30	22	48	MH	65	59	39	20	66.9	57.6	56.2	20.0	2.60
	(12-18)	Clay	0	31	20	49	MH	64	57	38	19	67.7	57.5	[illegible]	20.0	2.60
Albrook Satellite	0-3	Clay	0	11	31	58	MH	89	89	49	40	57.2	77.0	69.8	31.8	2.59
	3-6	Clay	0	5	36	59	MH	96	77	39	38	60.3	69.8	60.2	29.5	2.64
	(0-6)	Clay	0	8	34	58	MH	92	83	44	39	58.8	73.4	65.0	30.6	2.62
	6-9	Clay	0	7	35	58	MH	94	70	41	29	64.9	62.6	56.3	27.6	2.70
	9-12	Clay	0	7	36	57	MH	94	72	39	33	67.9	59.8	55.6	27.0	2.70
	(6-12)	Clay	0	6	36	58	MH	94	71	40	31	66.4	61.2	56.0	27.3	2.70
	12-15	Clay	0	6	36	58	MH	95	74	38	36	68.6	57.8	54.9	28.4	2.81
	15-18	Clay	0	13	37	50	MH	87	70	43	27	71.8	53.7	51.2	29.0	2.74
	(12-18)	Clay	0	10	36	54	MH	91	72	41	31	70.2	55.8	53.0	28.7	2.78

Soils Properties Summary
(Trafficability Layers)

Site	Soil Layer in.	U.S. Department of Agriculture Textural Classification	Mechanical Analysis Percent: Gravel	Sand	Silt	Clay	Unified Soil Classification System: Classification	Fines Percent	Atterberg Limits: LL	PL	PI	Dry Density pcf	Soil Moisture Content, Percent Dry Weight, Atmosphere Tension: 0.00	0.06	15.0	Specific Gravity
Ft. Kobbe Satellite	0-3	Clay	0	6	34	60	MH	94	82	47	35	58.4	81.3	72.4	30.9	2.56
	3-6	Clay	0	1	21	78	MH	99	70	40	30	59.4	75.9	60.9	28.9	2.59
	(0-6)	Clay	0	3	28	69	MH	96	76	44	32	58.9	78.6	66.6	29.9	2.58
	6-9	Clay	0	4	19	77	MH	96	66	37	29	61.2	72.7	55.0	27.0	2.60
	9-12	Clay	0	7	11	82	MH	96	63	33	30	61.1	70.0	58.3	26.2	2.61
	(6-12)	Clay	0	5	15	80	MH	96	64	35	29	61.2	71.4	56.6	26.6	2.60
	12-15	Clay	0	5	12	83	CH	97	63	30	33	62.1	68.1	56.8	26.9	2.64
	15-18	Clay	0	8	10	82	CH	95	68	33	35	64.8	63.1	53.8	27.4	2.67
	(12-18)	Clay	0	7	11	82	CH	96	66	32	34	63.5	[illegible]	55.3	27.2	2.66
Ft. Sherman Satellite	0-3	Clay	0	8	19	73	MH	93	100	74	26	38.7	127.1	118.2	42.7	2.48
	3-6	Clay	0	4	15	81	MH	96	100	66	34	44.6	100.3	88.4	42.1	2.55
	(0-6)	Clay	0	6	17	77	MH	94	100	70	30	41.6	113.7	103.3	42.4	2.52
	6-9	Clay	0	4	6	90	MH	96	100	64	36	47.7	93.3	76.2	40.4	2.57
	9-12	Clay	0	4	11	85	MH	96	97	63	34	52.3	80.0	68.8	40.4	2.61
	(6-12)	Clay	0	4	8	88	MH	96	98	64	35	50.0	86.6	72.5	40.4	2.59
	12-15	Clay	0	5	23	72	MH	96	95	63	32	53.8	76.3	70.1	39.7	2.63
	15-18	Clay	0	7	28	65	MH	93	98	66	32	50.9	76.2	69.8	39.8	2.66
	(12-18)	Clay	0	6	26	68	MH	94	96	64	32	52.4	76.2	70.0	39.8	2.64

Soil Properties Summary
(Genetic Layers)

Site	Horizon	U.S. Department of Agriculture Textural Classification	Mechanical Analysis Percent Gravel	Sand	Silt	Clay
	A11	Clay	0	13	29	58
	A12	Clay	0	18	20	62
Albrook Forest	A3	Clay	0	4	25	71
	B21	Clay	0	6	18	76
	B22	Clay	0	3	16	81
	BC	Clay	0	2	19	79
	A1	Silty Clay Loam to Silty Clay	0	10	50	40
	AB or B1	Silty Clay	0	14	41	45
Chiva Chiva	B2	Clay	0	17	31	52
	B3	Clay	0	13	21	66
	BC	Clay	0	12	21	67
	C	Clay	0	26	16	58
	A11	Silty Clay to Clay	0	4	40	56
	A12	Clay	0	7	33	60
	A3	Clay	0	4	32	64
Albrook Satellite	B1	Clay	0	4	30	66
	B21	Clay	0	5	25	70
	B22	Clay	0	5	28	67
	BC	Clay	0	4	26	70
	C	Clay	0	3	23	74
	A11	Clay	0	4	36	60
Ft. Kobbe Satellite	A12	Clay	0	6	30	64
	B21	Clay	0	13	30	57
	B22	Clay	0	2	13	85
	C	Clay	0	6	20	74
	A11	Silty Clay to Clay	0	14	40	46
	A12	Clay	0	13	34	53
Ft. Sherman Satellite	A13	Silty Clay	0	5	42	53
	A3	Clay	0	2	32	66
	B21	Silty Clay	0	3	41	56
	B22	Silty Clay	0	3	42	55
	B23	Silty Clay	0	3	46	51

Moisture-Strength-Density Summary

Albrook Forest Site, Soil Plot No. 1

Date	Cone Index per 6-in. Layer 0-6	6-12	12-18	Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From Ind. RI	Avg RI	Soil Moisture per 6-in. Layer Percent Dry Weight 0-6	6-12	12-18	Dry Density per 6-in. Layer pcf 0-6	6-12	12-18
2 Feb 65	199	311	364	0.62	191	354	35.9	31.4	32.2	58.1	74.8	75.8
9 Feb 65	195	361	402	0.78	269	412	31.7	30.4	31.3	70.4	59.8	59.5
16 Feb 65	228	408	524	0.84	358	465	30.0	27.7	27.0	-	-	-
23 Feb 65	153	344	503	2.66	890	392	31.6	29.7	29.9	66.3	74.0	75.3
2 Mar 65	236	474	610	1.09	497	540	30.2	28.4	29.2	65.1	74.9	73.7
9 Mar 65	279	492	569	1.55	700	561	28.4	27.5	28.0	64.0	73.1	77.7
16 Mar 65	373	599	639	-	-	683	27.5	26.6	26.9	72.1	71.9	73.8
23 Mar 65	245	401	595	1.50	690	457	29.1	27.5	27.5	-	78.0	54.4
30 Mar 65	198	445	604	-	-	507	27.8	27.4	28.2	-	-	-
6 Apr 65	241	415	572	1.89	761	473	26.3	25.9	26.4	-	71.4	80.6
13 Apr 65	200	415	600	1.82	753	473	26.5	26.1	26.6	63.7	72.8	77.2
20 Apr 65	232	478	626	1.59	818	545	26.1	26.2	26.4	-	74.2	81.2
27 Apr 65	236	486	548	0.98	424	554	24.7	25.8	26.5	-	76.5	79.1
4 May 65	201	507	710	1.72	876	578	26.5	26.3	26.4	-	80.5	76.0
11 May 65	159	361	619	1.36	511	434	38.7	31.6	29.6	67.5	76.4	75.2
18 May 65	80	140	146	1.62	240	160	43.7	39.2	37.3	71.0	81.0	82.1
25 May 65	79	111	128	0.79	88	126	42.7	38.4	39.1	67.9	79.6	79.2
1 Jun 65	61	86	80	1.10	94	98	44.1	39.2	39.3	68.2	76.8	77.0
8 Jun 65	68	104	100	1.01	102	116	47.8	40.4	41.0	67.9	77.2	75.8
15 Jun 65	96	132	123	1.26	159	150	45.5	38.0	37.6	69.1	77.1	80.0
22 Jun 65	67	104	117	1.06	111	118	47.0	40.4	38.5	65.5	76.9	78.3
29 Jun 65	57	101	122	1.04	105	115	46.7	39.6	40.2	64.8	77.8	77.9
6 Jul 65	77	115	108	1.01	117	131	47.4	40.0	40.0	68.0	79.0	78.3
13 Jul 65	88	141	155	1.13	165	161	44.3	38.8	37.9	68.8	79.2	80.8
20 Jul 65	68	112	133	0.99	113	128	48.2	40.3	39.2	68.9	77.4	81.2
27 Jul 65	66	99	103	1.02	102	113	50.7	41.1	41.8	63.7	75.0	77.8
3 Aug 65	73	116	122	1.03	119	132	47.9	41.0	41.7	67.7	75.7	75.5
10 Aug 65	73	99	106	1.15	114	113	48.1	40.8	41.0	67.7	75.2	75.1
17 Aug 65	81	116	103	1.02	118	132	47.2	40.1	42.0	69.8	79.6	78.3
24 Aug 65	66	103	119	1.08	111	117	48.1	41.6	42.8	72.0	78.3	78.0
31 Aug 65	57	98	108	0.99	96	112	52.6	42.4	45.4	63.2	78.1	75.7
7 Sep 65	71	115	120	0.96	111	131	48.8	43.3	40.7	70.6	77.2	79.8
14 Sep 65	63	100	119	0.95	95	114	51.9	43.9	47.5	68.2	76.1	75.0
21 Sep 65	61	109	128	1.06	116	124	51.9	42.1	43.3	69.2	76.5	77.7
28 Sep 65	54	94	115	0.99	92	107	54.1	44.1	44.1	67.5	76.7	79.4

5 Oct 65	76	108	10_	1.09	117	123	48.5	42.0	44.0	70.0	77.9	77.8
12 Oct 65	69	106	125	1.26	133	121	54.0	44.4	47.4	67.5	76.5	74.9
19 Oct 65	55	86	86	1.00	87	98	54.7	47.5	47.1	67.9	73.3	70.3
26 Oct 65	57	113	117	0.97	110	129	55.1	41.1	44.1	67.1	78.2	74.7
2 Nov 65	55	77	81	0.97	74	88	51.9	41.3	39.7	70.0	80.0	81.8
9 Nov 65	48	94	104	1.04	98	107	54.4	43.5	48.9	68.1	76.3	70.9
16 Nov 65	59	96	107	1.02	98	109	50.4	43.4	42.7	70.1	77.1	77.9
23 Nov 65	57	91	90	1.07	98	104	53.2	43.7	45.9	67.1	75.9	74.6
29 Nov 65	62	110	117	1.01	111	125	56.6	41.7	46.5	65.2	77.4	72.1
7 Dec 65	51	86	104	0.88	75	98	55.6	43.5	45.7	66.6	76.0	74.0
14 Dec 65	60	91	96	0.98	89	104	55.6	43.8	48.2	67.0	77.6	73.4
22 Dec 65	63	98	110	0.85	83	112	55.9	42.8	43.6	65.4	77.3	76.7
27 Dec 65	82	118	126	1.03	122	134	49.5	40.8	41.4	67.2	76.8	78.1
1966												
4 Jan 66	77	127	133	1.03	131	145	51.1	39.4	38.6	68.7	79.7	80.6
11 Jan 66	71	98	93	0.92	90	112	51.2	41.3	41.8	68.0	77.9	79.7
18 Jan 66	89	147	156	1.07	158	168	50.5	39.5	39.7	62.1	77.7	80.4
25 Jan 66	108	150	156	1.06	163	171	42.9	39.4	38.1	70.1	75.7	79.5
8 Feb 66	190	322	380	-	-	367	39.6	30.2	31.1	-	-	-
21 Feb 66	126	216	240	-	-	246	35.8	29.6	30.4	-	-	-

Moisture-Strength-Density-Summary

Chiva Chiva Site, Soil Plot No. 1

Date	Cone Index per 6-in. Layer 0-6	6-12	12-18	Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From Ind RI	Avg RI	Soil Moisture per 6-in. Layer Percent Dry Weight 0-6	6-12	12-18	Dry Density per 6-inch. Layer pcf 0-6	6-12	12-18
3 Feb 65	750	750	750	-	-	832	18.3	18.9	21.3	-	-	-
9 Feb 65	750	750	750	-	-	832	19.2	19.5	21.1	-	-	-
17 Feb 65	750	750	750	-	-	832	17.8	18.4	21.6	-	-	-
24 Feb 65	750	750	750	-	-	832	18.5	18.8	22.1	-	-	-
3 Mar 65	750	750	750	-	-	832	18.0	19.4	22.5	-	-	-
10 Mar 65	750	750	750	-	-	832	17.6	19.1	22.5	-	-	-
17 Mar 65	750	750	750	-	-	832	17.2	17.4	19.0	-	-	-
24 Mar 65	750	750	750	-	-	832	17.7	18,8	21.8	-	-	-
31 Mar 65	750	750	750	-	-	832	15.8	16.8	18.1	-	-	-
7 Apr 65	750	750	750	-	-	832	16.0	18.2	18.5	-	-	-
19 Apr 65	750	750	750	-	-	832	16.2	17.8	19.5	-	-	-
21 Apr 65	750	750	750	-	-	832	15.2	17.6	21.4	-	-	-
28 Apr 65	750	750	750	-	-	832	15.9	18.1	19.8	-	-	-
5 May 65	750	750	750	-	-	832	18.6	19.7	21.5	-	-	-
12 May 65	186	307	501	-	-	341	36.4	30.8	30.2	77.6	84.7	-
19 May 65	210	324	396	-	-	360	32.2	30.2	31.4	81.4	-	-
26 May 65	194	299	384	1.56	441	332	36.0	38.1	32.1	73.4	79.5	76.6
2 Jun 65	153	232	320	0.98	149	258	37.6	32.8	34.4	73.7	81.3	79.6
9 Jun 65	158	251	314	1.25	313	279	38.5	31.7	34.5	74.1	83.1	79.4
16 Jun 65	169	301	385	1.03	306	334	37.6	30.7	32.9	74.2	85.0	82.9
23 Jun 65	139	276	366	1.49	417	306	39.0	31.0	33.4	73.2	83.9	79.4
30 Jun 65	173	281	350	1.24	347	312	38.5	32.1	35.4	75.0	79.0	78.7
7 Jul 65	182	279	331	1.13	364	310	38.7	31.1	33.6	75.7	83.1	75.4
14 Jul 65	276	391	429	1.29	507	434	32.4	30.4	31.6	73.3	82.1	82.8
21 Jul 65	171	302	358	1.12	340	335	39.2	31.7	32.0	74.3	82.9	83.1
28 Jul 65	132	247	357	1.07	264	274	41.1	32.4	34.4	72.8	81.0	77.8
4 Aug 65	162	292	341	1.55	510	324	39.4	30.8	32.7	73.5	81.3	75.8
11 Aug 65	131	227	292	1.03	234	252	42.8	33.6	36.3	72.3	82.5	79.7
18 Aug 65	156	309	377	1.12	324	343	39.5	31.8	32.8	75.7	82.5	84.0
25 Aug 65	121	236	336	1.01	233	262	42.6	33.4	33.9	75.6	82.9	83.9
1 Sep 65	129	239	341	1.07	258	265	41.3	32.4	37.4	76.1	86.4	79.9
8 Sep 65	136	231	276	0.98	226	256	41.5	33.1	35.4	73.9	83.8	81.3
15 Sep 65	132	229	321	0.95	215	254	42.8	32.6	40.7	74.8	85.9	79.0
22 Sep 65	129	224	300	1.07	242	249	45.6	37.4	47.2	73.7	81.2	73.8
29 Sep 65	129	243	279	0.95	205	270	44.5	33.1	34.7	74.3	86.4	84.4

6 Oct 65	157	277	321	1.32	333	307	38.3	32.1	32.2	75.1	81.4	82.0
13 Oct 65	121	201	317	0.90	180	223	46.9	33.5	39.2	72.0	85.4	81.1
20 Oct 65	110	236	331	1.19	287	262	44.2	32.8	35.4	73.9	83.3	80.4
27 Oct 65	141	259	342	1.25	317	287	39.8	32.9	34.3	77.5	85.5	83.1
4 Nov 65	108	204	319	1.22	252	226	43.0	32.7	37.9	75.8	60.1	79.7
10 Nov 65	116	193	286	0.83	157	214	47.8	35.5	46.3	70.9	83.4	75.1
17 Nov 65	128	209	302	0.94	196	232	44.6	34.4	36.0	73.2	84.6	83.9
24 Nov 65	115	208	304	0.72	138	231	50.4	44.4	45.9	68.3	73.6	72.9
1 Dec 65	117	213	234	0.97	208	236	45.9	34.7	44.1	71.9	82.6	76.2
8 Dec 65	121	216	284	0.97	210	240	46.6	34.1	34.9	72.7	84.1	83.9
15 Dec 65	132	245	371	1.31	338	272	44.5	33.0	36.2	73.0	[illegible]	80.2
22 Dec 65	139	253	315	0.99	251	281	45.3	32.6	33.4	73.1	83.4	79.6
28 Dec 65	293	430	474	-	-	477	35.3	28.9	31.7	71.0	83.2	79.1
1966												
5 Jan 66	173	341	459	-	-	378	37.4	32.3	33.1	77.4	82.2	82.8
12 Jan 66	191	405	500	-	-	450	40.4	40.2	31.1	74.4	-	-
19 Jan 66	341	499	530	-	-	554	34.7	27.5	31.5	71.7	-	-
26 Jan 66	449	698	733	-	-	775	32.4	26.5	28.9	-	-	-
9 Feb 66	526	741	750	-	-	832	21.9	23.5	22.5	-	-	-
23 Feb 66	557	750	750	-	-	832	21.4	20.1	22.4	-	-	-
9 Mar 66	559	750	750	-	-	832	20.1	20.1	23.5	-	-	-

Moisture-Strength-Density Summary

Albrook Satellite Site

Date	Cone Index per 6-in. Layer 0-6	6-12	Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From Ind. RI	Avg. RI	Soil Moisture per 6-in. Layer Percent Dry Weight 0-6	6-12	Dry Density per 6-in. Layer pcf 0-6	6-12
1 Mar 65	191	360	1.05	378	367	31.1	28.2	65.5	71.2
15 Mar 65	192	388	1.20	466	396	31.8	28.7	-	72.0
29 Mar 65	187	327	1.44	471	334	29.6	29.3	55.0	57.0
12 Apr 65	170	324	1.44	466	330	30.7	29.0	-	71.9
26 Apr 65	232	423	1.41	596	431	28.9	26.7	-	-
10 May 65	125	219	1.32	289	223	35.3	29.1	71.7	76.8
24 May 65	91	119	0.83	99	121	44.7	41.0	67.2	76.0
7 Jun 65	67	107	0.94	101	109	44.8	40.4	65.8	73.9
22 Jun 65	46	90	0.90	81	92	47.4	44.4	66.3	74.8
6 Jul 65	90	119	1.04	124	121	46.6	41.0	66.4	74.4
22 Jul 65	70	122	1.02	124	124	45.3	42.3	71.1	74.2
2 Aug 65	89	137	1.08	148	140	49.0	41.3	61.8	73.7
16 Aug 65	77	119	0.90	107	121	49.2	42.3	65.6	73.7
30 Aug 65	61	114	1.00	114	116	52.3	42.6	68.6	76.9
13 Sep 65	54	67	1.03	69	68	53.0	46.5	66.1	72.8
30 Sep 65	49	104	0.93	97	106	63.0	44.6	62.2	74.8
14 Oct 65	49	97	1.01	101	99	59.4	46.1	62.2	73.7
28 Oct 65	54	86	0.98	84	88	56.6	43.4	64.5	75.7
12 Nov 65	56	90	1.43	129	92	56.4	44.3	64.4	75.7
26 Nov 65	51	102	1.00	102	104	56.9	44.4	64.1	72.9
9 Dec 65	48	99	0.92	91	101	54.7	43.6	66.7	71.6
21 Dec 65	52	92	0.98	90	94	58.0	44.2	65.6	76.7
6 Jan 66	67	119	1.03	122	105	58.4	45.5	65.2	74.2
20 Jan 66	104	148	0.98	145	151	49.8	42.9	63.6	73.1
3 Feb 66	101	179	0.96	172	182	48.6	37.5	63.6	74.8
17 Feb 66	127	204	0.86	175	208	43.5	35.1	70.4	75.7
3 Mar 66	147	226	-	-	231	38.6	34.0	64.4	76.7

Moisture-Strength-Density Summary

Albrook Satellite Site (cont'd)

Date	Cone Index per 6-in. Layer		Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From		Soil Moisture per 6-in. Layer Percent Dry Weight		Dry Density per 6-in. Layer pcf	
	0-6	6-12		Ind. RI	Avg. RI	0-6	6-12	0-6	6-12
17 Mar 66	184	421	-	-	429	33.5	28.6	56.5	66.4
31 Mar 66	231	453	-	-	462	32.3	29.0	58.9	66.3
14 Apr 66	198	415	-	-	423	31.3	28.4	59.8	68.6
28 Apr 66	85	128	0.96	123	130	41.6	41.2	66.9	74.6
12 May 66	63	110	0.98	108	112	47.5	42.6	69.3	77.6
26 May 66	58	96	0.94	90	98	52.0	44.0	69.0	75.7
9 Jun 66	51	104	0.96	100	106	50.1	43.8	69.5	75.0
23 Jun 66	50	94	0.90	85	96	47.8	54.6	69.9	70.8
7 Jul 66	51	105	1.00	105	107	55.6	45.1	66.0	73.8
21 Jul 66	56	109	0.92	100	111	56.7	44.2	64.5	73.8
4 Aug 66	58	105	1.05	111	107	52.1	43.5	67.5	76.7
18 Aug 66	55	97	1.26	122	99	54.7	47.9	66.0	70.9
1 Sep 66	65	115	1.14	131	117	56.2	40.6	65.4	74.6
15 Sep 66	56	97	0.88	85	99	57.0	46.4	67.4	71.2
29 Sep 66	54	108	0.99	107	110	57.8	44.6	64.2	74.3
13 Oct 66	67	103	0.90	93	105	58.1	47.6	61.6	69.0
27 Oct 66	58	123	0.92	113	125	58.3	45.1	64.8	73.3
9 Nov 66	46	91	0.92	84	93	56.0	45.9	66.5	73.7
21 Nov 66	45	90	0.85	76	92	56.2	43.5	64.0	76.8
9 Dec 66	39	84	0.78	66	86	66.6	48.8	59.0	71.2
21 Dec 66	81	139	-	-	142	59.7	43.1	62.3	73.9
5 Jan 67	98	138	-	-	141	49.2	42.8	63.8	71.7
20 Jan 67	176	282	-	-	288	39.1	33.6	66.8	71.5
30 Jan 67	106	176	-	-	180	41.8	37.0	66.0	70.1

Moisture-Strength-Density Summary

Fort Kobbe Satellite Site

Date	Cone Index per 6-in. Layer		Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From		Soil Moisture per 6-in. Layer Percent Dry Weight		Dry Density per 6-in. Layer pcf	
	0-6	6-12		Ind. RI	Avg. RI	0-6	6-12	0-6	6-12
4 Mar 65	273	561	-	-	617	29.9	27.2	62.0	73.2
15 Mar 65	293	601	-	-	661	26.6	25.8	-	-
[illegible] Mar 65	197	433	-	-	476	26.7	26.3	-	69.3
12 Apr 65	215	377	1.61	607	415	23.6	24.8	-	-
26 Apr 65	274	518	-	-	570	23.9	25.9	-	-
10 May 65	173	404	1.24	501	444	31.3	29.9	75.2	47.7
24 May 65	79	141	1.07	151	155	44.0	39.3	68.7	76.5
7 Jun 65	76	141	0.90	127	155	48.0	39.6	73.8	75.6
21 Jun 65	118	195	1.20	234	214	41.7	36.3	62.4	74.8
6 Jul 65	142	192	1.24	238	211	42.2	38.4	64.2	76.1
22 Jul 65	178	265	1.28	340	293	34.4	31.8	63.2	75.6
2 Aug 65	94	174	1.19	207	191	39.2	36.4	67.5	74.5
16 Aug 65	100	148	1.14	169	163	45.0	38.9	63.1	75.9
30 Aug 65	65	99	1.10	109	109	49.7	44.0	72.1	76.0
16 Sep 65	102	180	1.00	180	198	48.9	38.0	63.2	75.4
30 Sep 65	69	134	1.05	141	147	56.1	42.1	63.8	76.6
14 Oct 65	63	118	1.13	133	130	50.8	43.2	68.7	76.1
28 Oct 65	53	116	1.04	121	128	57.5	40.7	64.6	77.6
12 Nov 65	64	128	1.04	133	141	57.0	41.8	64.8	76.8
26 Nov 65	43	101	1.09	110	111	63.9	52.4	57.6	72.0
9 Dec 65	59	112	1.12	125	123	57.1	42.7	64.2	77.3
23 Dec 65	108	161	1.00	161	177	47.2	38.7	67.4	75.8
6 Jan 66	128	257	0.91	234	253	39.7	35.8	63.9	75.8
20 Jan 66	131	312	-	-	343	36.6	33.2	59.2	73.5
3 Feb 66	277	473	-	-	520	30.3	28.2	62.4	-
17 Feb 66	357	633	-	-	696	24.1	25.6	-	-
3 Mar 66	200	432	-	-	475	26.1	24.1	56.6	67.9

Moisture-Strength-Density Summary

Fort Kobbe Satellite Site (Cont'd)

Date	Cone Index per 6-in. Layer 0-6	Cone Index per 6-in. Layer 6-12	Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From Ind. RI	Rating Cone Index (RCI), 6 to 12 in. From Avg. RI	Soil Moisture per 6-in. Layer Percent Dry Weight 0-6	Soil Moisture per 6-in. Layer Percent Dry Weight 6-12	Dry Density per 6-in. Layer pcf 0-6	Dry Density per 6-in. Layer pcf 6-12
17 Mar 66	330	690	-	-	759	24.5	24.9	57.5	59.2
31 Mar 66	238	566	-	-	623	25.6	27.3	58.9	-
14 Apr 66	351	626	-	-	689	24.2	26.6	-	62.8
28 Apr 66	156	404	-	-	444	29.5	26.5	58.1	66.1
12 May 66	99	151	1.01	152	166	43.5	37.8	72.5	81.5
26 May 66	44	98	-	-	108	50.3	41.0	68.5	76.0
9 Jun 66	52	113	1.42	160	124	58.8	53.2	61.4	71.0
23 Jun 66	95	180	-	-	198	45.8	37.4	62.9	78.4
7 Jul 66	68	126	1.01	127	139	52.4	44.3	64.3	74.8
21 Jul 66	59	92	0.92	85	101	51.4	44.3	67.1	74.5
4 Aug 66	95	121	1.03	125	133	46.1	43.0	71.0	75.9
18 Aug 66	69	109	1.08	118	120	54.2	42.7	64.8	76.6
1 Sep 66	92	139	0.97	135	153	48.0	39.1	69.4	79.7
15 Sep 66	56	107	0.95	102	118	51.8	44.2	67.2	73.9
29 Sep 66	79	126	-	-	139	49.7	40.8	65.4	71.2
14 Oct 66	63	103	-	-	113	54.8	46.2	65.1	71.8
27 Oct 66	68	120	1.00	120	132	49.6	42.3	69.0	76.8
10 Nov 66	70	99	-	-	109	55.2	45.7	62.7	71.1
21 Nov 66	70	116	1.05	122	118	55.0	41.6	64.7	71.4
8 Dec 66	80	129	-	-	142	54.6	42.2	67.2	77.3
22 Dec 66	77	115	-	-	126	46.5	41.0	71.2	75.1
5 Jan 67	134	167	-	-	184	39.2	36.2	65.3	79.6
20 Jan 67	246	468	-	-	515	30.6	29.8	58.7	63.9
30 Jan 67	180	380	-	-	418	33.1	30.6	59.2	65.4

Moisture-Strength-Density Summary

Fort Sherman Satellite Site

Date	Cone Index per 6-in. Layer 0-6	Cone Index per 6-in. Layer 6-12	Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From Ind. RI	Rating Cone Index (RCI), 6 to 12 in. From Avg. RI	Soil Moisture per 6-in. Layer Percent Dry Weight 0-6	Soil Moisture per 6-in. Layer Percent Dry Weight 6-12	Dry Density per 6-in. Layer pcf 0-6	Dry Density per 6-in. Layer pcf 6-12
11 Mar 65	145	235	0.93	219	242	58.8	52.8	52.7	40.2
25 Mar 65	170	280	-	-	288	56.2	48.5	59.4	-
8 Apr 65	196	340	1.29	439	350	49.[illegible]	44.4	58.5	63.4
22 Apr 65	112	153	-	-	158	67.3	50.6	54.5	62.7
6 May 65	133	287	-	-	296	56.3	47.3	60.0	67.8
20 May 65	102	143	1.08	154	147	66.7	56.8	52.7	60.6
3 Jun 65	85	149	1.10	164	153	74.3	58.9	44.6	59.0
17 Jun 65	87	157	0.92	144	162	66.0	57.7	56.4	53.4
1 Jul 65	93	115	0.92	106	118	65.7	56.3	57.8	63.7
15 Jul 65	117	191	1.08	206	197	73.1	54.4	46.6	61.9
29 Jul 65	108	170	1.00	170	175	65.7	53.4	56.8	61.0
13 Aug 65	72	145	0.96	139	149	74.8	64.9	52.7	55.5
26 Aug 65	65	81	0.98	79	83	71.5	65.1	54.2	57.6
9 Sep 65	78	130	1.10	143	134	80.8	60.8	49.4	58.9
23 Sep 65	75	128	1.00	128	132	84.4	64.5	48.6	58.1
7 Oct 65	80	142	1.19	169	146	81.8	54.8	49.5	65.2
21 Oct 65	89	186	1.16	216	192	66.3	50.2	59.2	66.8
5 Nov 65	62	104	1.04	108	107	79.3	69.7	49.9	55.5
18 Nov 65	71	124	1.03	128	128	81.0	65.7	51.2	58.6
2 Dec 65	74	111	0.90	100	114	80.0	66.6	50.3	56.4
16 Dec 65	90	156	1.04	162	161	76.8	56.5	52.2	62.7
29 Dec 65	69	123	1.02	125	127	85.6	65.2	47.8	57.8
13 Jan 66	82	152	0.99	150	156	75.8	59.4	52.4	59.6
27 Jan 66	114	188	1.14	214	194	69.5	51.0	52.2	65.9
10 Feb 66	119	181	1.06	192	186	66.2	56.0	50.7	60.0
24 Feb 66	169	341	-	-	351	57.4	48.4	48.4	60.7
10 Mar 66	126	234	-	-	241	59.4	49.7	51.9	-

Moisture-Strength-Density Summary

Fort Sherman Satellite Site (Cont'd)

Date	Cone Index per 6-in. Layer 0-6	Cone Index per 6-in. Layer 6-12	Remolding Index (RI), 6 to 12 in. Layer	Rating Cone Index (RCI), 6 to 12 in. From Ind. RI	Rating Cone Index (RCI), 6 to 12 in. From Avg. RI	Soil Moisture per 6-in. Layer Percent Dry Weight 0-6	Soil Moisture per 6-in. Layer Percent Dry Weight 6-12	Dry Density per 6-in. Layer pcf 0-6	Dry Density per 6-in. Layer pcf 6-12
24 Mar 66	247	389	-	-	401	47.8	43.2	60.8	64.5
7 Apr 66	153	235	-	-	242	58.5	50.6	51.3	62.2
21 Apr 66	79	130	0.94	122	134	70.9	59.1	51.4	60.9
5 May 66	67	126	-	-	130	74.7	60.7	50.4	59.6
19 May 66	75	137	-	-	141	73.8	60.0	51.4	61.2
2 Jun 66	98	179	0.98	175	184	63.4	52.6	60.8	66.2
16 Jun 66	76	141	-	-	145	73.9	62.2	53.1	58.3
30 Jun 66	90	15[illegible]	0.99	152	159	73.7	53.8	53.4	64.8
14 Jul 66	78	136	-	-	140	[illegible].1	59.5	51.1	61.5
28 Jul 66	88	149	-	-	153	69.1	58.8	55.6	61.6
11 Aug 66	89	177	-	-	182	69.4	51.7	56.7	67.5
25 Aug 66	76	142	-	-	146	72.3	57.0	55.3	63.4
22 Sep 66	73	142	1.00	142	146	78.8	57.9	52.2	62.0
6 Oct 66	104	189	-	-	195	68.0	57.6	55.5	63.0
20 Oct 66	96	169	-	-	174	62.8	50.5	59.0	65.3
10 Nov 66	86	164	-	-	169	63.1	51.0	59.4	64.2
17 Nov 66	64	121	0.96	116	125	70.[illegible]	58.6	53.9	60.4
5 Dec 66	88	147	-	-	151	69.4	59.4	55.8	61.2
15 Dec 66	77	165	-	-	170	69.0	53.0	55.0	63.7
29 Dec 66	60	137	-	-	141	75.4	61.2	50.8	57.5
12 Jan 67	89	162	-	-	167	76.8	59.6	51.4	57.4
26 Jan 67	173	303	-	-	312	53.5	47.5	56.3	59.4

Soil Moisture Summary
(per three-inch layer)

Albrook Forest Site, Soil Plot No. 1

Date	Layer					
	0-3	3-6	6-9	9-12	12-15	15-18
2 Feb 65	38.1	33.7	31.4	31.4	32.0	32.3
9 Feb 65	33.3	30.1	29.7	31.0	31.1	31.5
16 Feb 65	30.9	29.2	27.7	27.7	28.1	26.0
23 Feb 65	32.4	30.7	29.8	29.6	29.9	29.9
2 Mar 65	31.1	29.3	28.4	28.3	29.2	29.2
9 Mar 65	28.9	27.9	27.3	27.7	28.1	27.9
16 Mar 65	27.8	27.2	26.3	26.8	27.1	26.8
23 Mar 65	29.7	28.4	27.2	27.8	27.7	27.4
30 Mar 65	27.4	28.2	27.4	27.5	28.6	27.8
6 Apr 65	26.5	26.0	25.9	26.0	26.3	26.6
13 Apr 65	26.9	26.2	25.8	26.4	26.6	26.7
20 Apr 65	26.2	25.9	26.0	26.4	26.4	26.3
27 Apr 65	23.9	25.5	25.6	26.1	26.3	26.8
4 May 65	27.0	25.9	26.0	26.6	26.5	26.4
11 May 65	41.4	36.0	32.5	30.8	29.2	30.0
18 May 65	47.2	40.3	39.0	39.4	38.2	36.5
25 May 65	44.3	41.1	37.8	39.0	39.1	39.0
1 Jun 65	47.1	41.1	39.4	38.9	39.3	39.1
8 Jun 65	52.4	43.2	40.5	40.3	40.8	41.1
15 Jun 65	50.3	40.6	37.4	38.6	37.4	37.8
22 Jun 65	50.1	43.9	40.4	40.4	39.0	37.9
29 Jun 65	49.1	44.3	39.5	39.7	40.3	40.1
6 Jul 65	53.0	41.8	39.8	40.3	40.2	39.9
13 Jul 65	47.9	40.7	39.0	38.6	39.1	36.7
20 Jul 65	53.1	43.3	40.6	40.1	39.6	38.7
27 Jul 65	55.5	44.9	41.6	40.7	42.0	41.7
3 Aug 65	52.2	43.6	41.0	41.0	41.7	41.6
10 Aug 65	53.1	43.2	41.0	40.7	40.8	41.3
17 Aug 65	52.3	42.1	39.2	41.0	43.3	40.6
24 Aug 65	53.1	42.9	41.2	42.0	42.8	42.9
31 Aug 65	60.8	44.5	42.3	42.6	45.0	45.8
7 Sep 65	55.4	42.3	41.2	45.5	41.1	40.3
14 Sep 65	58.1	45.7	42.9	44.9	46.0	48.9
21 Sep 65	58.9	44.8	41.9	42.3	43.1	43.5
28 Sep 65	61.8	46.3	43.8	44.4	45.3	43.1
5 Oct 65	55.8	43.6	41.3	42.6	43.9	44.2
12 Oct 65	61.3	46.9	45.2	43.6	47.7	47.4
19 Oct 65	62.0	47.3	45.2	49.9	47.1	47.2
26 Oct 65	64.1	46.2	41.2	40.9	43.6	44.6
2 Nov 65	59.7	44.2	41.2	41.3	41.1	38.3

Soil Moisture Summary
(per three-inch layer)

Albrook Forest Site, Soil Plot No. 1 (Cont'd)

Date	Layer 0-3	3-6	6-9	9-12	12-15	15-18
9 Nov 65	61.9	46.9	43.2	43.8	47.3	50.6
16 Nov 65	57.0	43.8	42.9	44.0	43.3	42.1
23 Nov 65	59.5	46.8	43.7	43.7	45.6	46.3
29 Nov 65	67.3	45.8	41.5	41.9	46.1	46.8
7 Dec 65	64.6	46.5	43.5	43.5	45.0	46.3
14 Dec 65	64.7	46.5	43.6	43.8	46.8	49.5
22 Dec 65	66.3	45.5	42.6	42.9	41.7	45.5
27 Dec 65	55.5	43.6	40.4	41.2	41.7	41.1
4 Jan 66	[illegible]9.6	42.6	39.7	39.1	38.9	38.3
11 Jan 66	57.7	44.7	41.6	41.1	41.7	41.9
18 Jan 66	55.8	45.2	40.0	38.9	39.8	39.5
25 Jan 66	46.3	39.6	37.4	41.4	38.4	37.9
8 Feb 66	47.5	31.8	30.1	30.5	31.6	30.5
21 Feb 66	31.6	39.9	30.6	28.7	30.8	29.8

Soil Moisture Summary
(per three-inch layer)

Chiva Chiva Site, Soil Plot No. 1

Date	Layer 0-3	3-6	6-9	9-12	12-15	15-18
3 Feb 65	17.8	18.7	18.8	18.9	21.0	21.9
9 Feb 65	19.1	19.4	19.1	19.9	20.6	21.6
17 Feb 65	18.0	17.7	17.7	19.1	20.7	22.6
24 Feb 65	18.3	18.7	18.4	19.1	21.8	22.4
3 Mar 65	17.3	18.9	18.8	20.1	21.9	23.2
10 Mar 65	17.1	18.2	18.5	19.8	22.1	23.0
17 Mar 65	16.2	18.2	17.4	17.5	18.7	19.3
24 Mar 65	16.9	18.6	18.3	19.4	21.1	22.6
31 Mar 65	14.8	16.7	16.4	17.2	18.3	17.9
7 Apr 65	15.2	16.9	17.6	18.8	18.2	18.8
14 Apr 65	15.2	17.1	17.3	18.3	19.1	19.8
21 Apr 65	14.1	16.4	16.7	18.4	22.6	20.3
28 Apr 65	14.8	16.9	17.0	19.2	20.0	19.6
5 May 65	18.5	18.7	18.1	19.4	21.1	21.9
12 May 65	38.3	34.5	31.1	30.6	30.7	29.7
19 May 65	36.3	30.7	30.1	30.3	30.7	32.2
26 May 65	38.3	33.7	31.8	32.9	32.4	31.8
2 Jun 65	39.6	35.7	33.1	32.7	33.8	35.1
9 Jun 65	41.9	35.1	31.7	31.7	34.5	34.5
16 Jun 65	37.5	35.6	30.6	30.7	32.4	33.5
23 Jun 65	42.9	35.3	31.0	31.1	32.6	34.2
30 Jun 65	42.4	34.6	31.4	32.8	35.6	35.1
7 Jul 65	44.0	33.4	30.9	31.4	33.6	33.6
14 Jul 65	34.0	30.8	30.2	30.7	31.1	32.2
21 Jul 65	43.5	34.9	31.6	31.8	31.4	32.6
28 Jul 65	45.7	36.5	32.7	32.2	34.2	34.6
4 Aug 65	45.3	33.6	30.5	31.1	32.5	32.9
11 Aug 65	48.4	37.2	33.2	33.9	35.9	36.7
18 Aug 65	45.4	33.6	31.9	31.6	31.9	33.8
25 Aug 65	47.9	37.2	34.3	32.6	33.2	34.5
1 Sep 65	46.9	35.8	32.3	32.5	35.2	39.6
[illegible] Sep 65	45.8	37.2	33.0	33.1	34.4	36.4
15 Sep 65	50.3	35.6	31.2	34.0	39.3	42.1
22 Sep 65	51.8	39.4	34.0	40.6	44.7	49.6
29 Sep 65	51.4	37.7	33.5	32.7	34.1	35.4
6 Oct 65	42.4	34.1	31.6	32.4	33.7	30.6
13 Oct 65	54.7	39.1	33.1	34.0	38.0	39.5
20 Oct 65	51.3	37.1	32.0	33.6	35.2	35.7
27 Oct 65	45.1	34.5	31.6	34.3	32.9	35.7
4 Nov 65	51.6	34.4	33.0	32.4	36.9	39.5

Soil Moisture Summary
(per three-inch layer)

Chiva Chiva Site, Soil Plot No. 1 (Cont'd)

Date	Layer					
	0-3	3-6	6-9	9-12	12-15	15-18
10 Nov 65	55.1	40.6	34.7	36.3	41.0	51.8
17 Nov 65	51.0	38.2	35.0	33.7	35.4	36.6
24 Nov 65	55.6	45.3	43.9	45.0	46.4	45.5
1 Dec 65	53.4	38.3	35.3	34.1	36.9	51.3
8 Dec 65	53.9	39.2	34.6	33.6	33.8	35.9
15 Dec 65	51.7	37.3	33.1	32.9	35.7	36.7
22 Dec 65	52.2	38.3	32.6	32.6	34.1	42.6
28 Dec 65	39.9	30.8	28.7	29.0	31.8	31.7
5 Jan 66	40.0	34.7	31.6	33.0	33.2	33.1
12 Jan 66	45.9	34.8	30.3	30.1	30.9	31.4
19 Jan 66	39.0	30.4	27.3	27.8	28.8	34.2
26 Jan 66	35.7	29.1	26.3	26.6	28.8	28.9
9 Feb 66	24.8	19.1	21.1	25.8	22.5	22.5
23 Feb 66	21.7	21.2	20.2	19.9	22.0	22.9
9 Mar 66	20.4	19.8	19.7	20.4	23.3	23.8

- APPENDIX B -

SEED STABILITY AND GERMINATION, AND CHARACTERISTICS OF SOME SEEDLINGS OF TROPICAL FOREST TREES

Seed Stability and Germination, and Characteristics of Some Seedlings of Tropical Forest Trees*

Introduction

A limited study of seeds and seedlings was made to establish facts about seed stability and seedling characteristics for some of the most frequently encountered tree species in the Canal Zone. The ripe seeds of some tropical forest trees fall on moist earth or into forest litter and germinate almost immediately. Other seeds appear to remain dormant indefinitely, even in moist soil or wet forest litter. Salisbury[25] reported a highly variable tendency for seeds to germinate immediately after falling.

Methods of Study

The collectors of vegetation specimens for the Tropic Test Center Data Base herbarium made collections of ripe seeds or fruits, as they were found. The seeds and fruits were placed in paper bags numbered to correspond with the parent plant. Some specimens of each specie of seed were planted in paper cups filled with vermiculite. Developing seedlings were allowed to grow until growth ceased, at which time the seedlings were pressed, dried, and mounted for retention in the herbarium. Other specimens were placed in storage for subsequent examination.

Results

Ripe seeds from 221 species of trees and shrubs were collected. Ninety, or 41 percent, of the collected seeds germinated and produced seedlings of some size. Seeds which failed to germinate usually rotted after standing for eight to ten weeks in the moist vermiculite. Planted seeds which remained hard and bright for ten weeks were scored and further tested for ability to germinate. Scoring always resulted in swelling and rapid decay of the seed. In no instance did scoring produce germination.

In addition to germination tests the collected seeds were stored for six months and observed for stability of the seed during a storage period. Of the 90 seed species which germinated, 38, (42 percent) remained hard and bright after storage. On the other hand only 36 of 131 seeds (27 percent), of the species which failed to germinate remained hard and bright after storage. The remainder of the seeds had completely decayed after six months.

Table B is a listing, by family, of the species included in the seed germination test. The number of specimens whose seeds were successfully

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* This section has been prepared by Dr. Robert Hutton, Biologist, and Dr. Edwin Tyson. The assistance of Elinor V. Hutton is acknowledged.

germinated and/or stored for six months without deterioration, as well as the number of individuals of each species observed is indicated.

TABLE B. GERMINATION AND STORAGE OF TROPICAL FOREST SEEDS
Successful storage based on retention of form for six months

Family	Genus-Species	Collector's No.	Successful Germination	Successful Storage	Number of Separate Collections Observed
ANACARDIACEAE	Anacardium occidentalo	3573	1	1	1
ANNONACEAE	Unoniopsis	3486		1	1
	Annona	4348		1	1
APOCYNACEAE		3910	1		1
ARACEAE		3954	1		1
		3963	1		1
		4486	1		1
		4494			1
		4498		1	1
ARISTOLOCHINACEAE	Aristolochia maxima	4179	1	1	1
BIGNONIACEAE	Crescentia cujete L	3797 3565	1	1	2
	Tecoma Stans L./Juss	3569			1
	Tabebuia	4456	1	1	1
BIXACEAE	Bixa orellana	4223 4522	1	1	2
BOMBACACEAE		B2239	1	1	1
	Ochroma limonensis Rowlee	3676		1	1
BORAGINACEAE	Cordia alba	4289			1
BURSERACEAE	Bursera semiruba Sarg.	3542	1		1
CANNACEAE	Canna	4677		1	1

Family	Genus-Species	Collector's No.	Successful Germination	Successful Storage	Number of Separate Collections Observed
CAPRIFOLIACEAE		B2630			1
OCHLOSPERMACEAE	Cochlospermum vitifolium (Willd) Spreng.	3557		1	1
CAESALPINIACEAE	Cassia fistulosa L	3469	1	1	1
	Rauhinis	4006	1		1
	Hymenaea	4268			1
COMPOSITAE	Veronia canescens HBK	3477			1
		3903			1
		3923			1
		3974		1	1
	Eupatorium ordoratum L.	3793	1		1
CONNARACEAE	Cnestidium rufescens Planch	3571		1	1
	Connarus williamsii Britton	3829	1		1
CLUSIACEAE	Rheedia	3721	1	1	1
	Clusia	3964	1	2	2
	Clusia	4357			
CUCURBITACEAE	Luffa cylindrica L.	3506		1	1
CYCLANTHACEAE		4359			1
DILLENIACEAE	Curatella americana	B2237	1		1
	Davilla as[illegible]a	3616	1		1
		3790		1	1
	Tertacera volubilis	3480		1	1
EUPHORBIACEAE	Latropha	3955			1
	Ricinus communis	4129		1	1

Family	Genus-Species	Collector's No.	Successful Germination	Successful Storage	Number of Separate Collections Observed
FABACEAE	Erythrina rubrinervia	B2238	1		
	Erythrina costaricensis	B2440-A 3724	1	1	2
	Ormosia coccinea	3472	1	1	1
	Indigofera panamensis	3474			1
	Cajanus bicolor	3551	1		1
	Gliricidum sepium	3626 3723 3781	2	1	3
	Flemingia strobilifera	3752	1	1	1
	Securidaca diversifolia	3757	1	1	1
	Dioclea	3926	1	1	1
FLACOURTIACEAE	Casearia arguta	3730			1
	Xilosma panamensis	3771			1
LOGANIACEAE	Strychnos panamensis Seem.	3570		1	1
LYTHRACEAE	Adendria floribunda	3751			1
MALPHIGHIACEAE	Serjania mexicana (L.)	3479			1
	Heterapteris	3654	1	1	1
	Bunchosia cornifolia H.B.K.	3795			1
MALVACEAE		3539	1	1	1
	Hibiscus tiliaceus L.	3778		1	1
MELASTOMACEAE	Miconia	B2296 3782 4728 4770	1	1	4
	Miconia cf. prasina	3534 4043			2
	Miconia argentia (Sw.)	3709			1
	Clidemia rubra	3763 4322			2
		3806		1	1
		3862			1
		3968			1
		4064			1

Family	Genus-Species	Collector's No.	Successful Germination	Successful Storage	Number of Separate Collections Observed
MELASTOMACEAE (Cont'd)					
	Miconia impetiolaris	4117		1	1
		4516			1
	Miconia lacera Humb. & Bond.	4550	1		1
MIMOSACEAE	Enterolobium Cyclocarpum	3663			1
	Inga	3665	1	1	1
	Cassia undulata	3762	1	1	1
MORACEAE	Ficus	3464 3575			2
	Ficus benjamina L.	3485			1
	Ficus obtusifolia H.B.K.	4018	1		1
	Ficus insipida Willd.	4124 4142			2
MYRSINACEAE	Ardisia	3605 3735	2	1	2
MYRTACEAE	Psidium guajaval	3630	1	1	1
	Eugenia	4333	1		1
	Eugenia malaccensis	4514			1
NYCTAGINACEAE	Neea laetevirens	4141			1
ONAGRACEAE	Fuchsia	B2429			1
PHOENICACEAE		4491	1		1
PINGUICULACEAE	Utricularia pusilla Vahl.	2471		1	1
PIPERACEAE	Piper eduncum	B2442			1
	Piper tuberculatum Jacq.	3562	1		1
	Piper	3765 3766 3890 3933 3949 3953 4067 4087 4714	2		9

Family	Genus-Species	Collector's No.	Successful Germination	Successful Storage	Number of Separate Collections Observed
PHAMNACEAE	Cotenva	3558		1	1
ROSACEAE	Hirtella racemosa Sw.	3713	1		1
RUBIACEAE	Alibertia edulis	3734	1	1	1
	Psychotria undata	3787	1		1
	Genipa americana L.	4009	1	1	1
		3951			1
	Amioua corymarsa	4061	1	1	1
	Palicourea guinensis	4368		1	1
SAPINDACEAE		B2345	1		1
	Sapindus sapronaria L.	3481		1	1
	Serjania	3568 3615 3670	2	2	3
	Allophylus occidentalis (Sw.)	4283	1	1	1
	Talisia	4336			1
		4540	1		1
SAPOTACEAE		4671	1	1	1
SOLANACEAE		B2292			1
	Solanum	4479 4350 B2419	1		3
	Solanum diversifolia				
	Schlecht	3584			1
		3942			1
		4079	1		1
TILIACEAE	Apeiba tibourbou Aubl.	3555	1	1	1
	Belotia panamensis Pittier	3705			1
	Luehea seemannii Triana & Planck	3887	1		1
VERBENACEAE	Tectona grandis L	2791			1
	Citharexylum caudatum	3780		1	1

Family	Genus-Species	Collector's No.	Successful Germination	Successful Storage	Number of Separate Collections Observed
VERBENACEAE (Cont'd)					
	Lantana camara	4105	1		1
VITACEAE		38[illegible]			1
	Cissus	465[illegible]			1
VIOLACEAE		3830			1
SPECIMENS NOT CLASSIFIED		----	30	15	77
Number of observations			90	71	221
Per cent of total			41	32	

The difficulty in identifying seedlings and in relating them to mature trees has been recognized. Richards[26] cites "very striking differences in the form and structure of the leaves (and often their arrangement) between young and mature individuals of tree". Seedlings developing from collected seeds for the current study differed greatly from the mature forms in both structure and arrangement. Figures B-1 through B-15, which show paired photographs of seedlings and the herbarium specimens of mature plants, are provided to illustrate these differences.

Observations

The work reported here answers few, if any, questions about forest ecology. On the other hand, some of the problems and difficulties associated with work in the tropical forest are made apparent. For example:

a. Progressive changes in leaf form and plant structure as plants age, preclude the development and use of any known form of dichotomous key based on vegetative characteristics of individuals.

b. Without prior observations to establish the relationships between seeds, seedlings, and mature trees, any attempt to observe processes of forest succession would be almost impossible.

c. Times of germination and rates of growth of seedlings maintained under artificial conditions do not parallel the behavior of seeds and seedlings in the natural environment.

Much more should be known about the behavior of tree seeds in tropical forest environments. These attempts to grow seedlings in pots indicate strongly that seed germination is influenced by interactions between the seed and the forest environment. Adequate knowledge of factors important in tropical forest ecology should include known facts on the effect of light, heat, moisture, acidity, and reaction to microorganisms. Larger animal forms may also play a part in seed behavior as well as dispersal. Bird or other animal passage may influence both germination and dispersal. Insect "damage" could cause an otherwise dormant seed to germinate. A number of these factors are more or less influenced by human activity.

Continued work might well have long-range importance to the military. The defoliation of forested areas will greatly disturb normal processes of forest succession because growth requiring abundant light will be abnormally encouraged. The effects of fire will have direct bearing on seed germination as well as an indirect influence through forest floor and canopy changes.

Photographed 4 months 10 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: VERAGUAS
MYRSINACEAE
Ardisia.

Canazas, in brush forest.
12' tall, 3" dbh, fruit black.

Coll. Edwin L. Tyson.

Det.

Seedling Photo: E. Hutton.

No. 3605

ETC-RE Label 1
1 Apr 67

FIGURE B-1. SPECIMEN NO. 3605

Photographed 4 months 11 days after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: VERAGUAS

MYRTACEAE

Psidium guajava L.

Canazas.
20' tall, 6" dbh, fruit yellow.

Coll. Edwin L. Tyson.

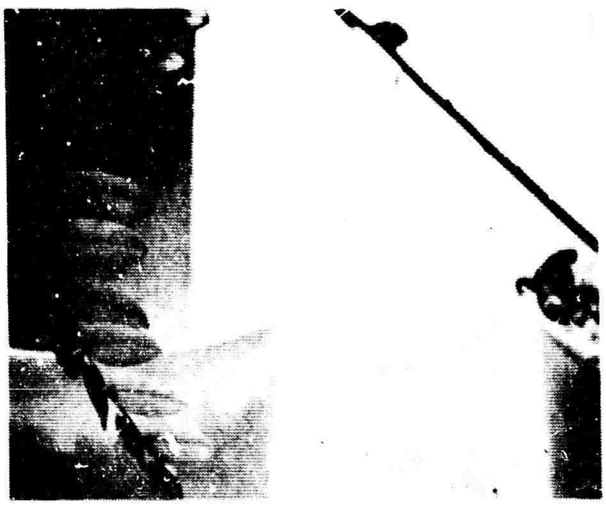
Det. J.D. Dwyer.

Seedling Photo: E. Hutton.

No. 3630

ETC-RE Label 1
1 Apr 67

FIGURE B-2. SPECIMEN NO. 3630



Photographed 4 months 12 days
after planting

US ARMY TROP. : TEST CENTER
Fort Clayton, Cr 1 Zone

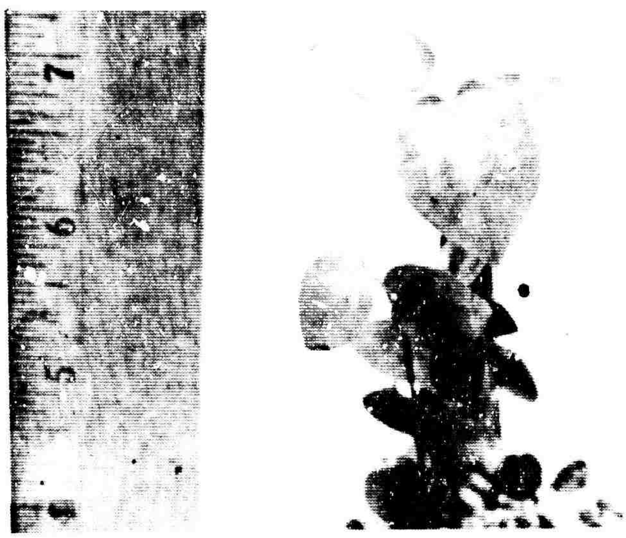
COUNTRY: PANAMA PROVINCE: CANAL ZONE
LYTHRACEAE
Adenaria floribunda HBK.

Road from Fort Sherman to Fort San Lorenzo.
8' tall, flowers white, primary succession.
Coll. Edwin L. Tyson & Kurt E. Blum. (Shrub.

Det. J.D. Dwyer, 1966.
Seedling Photo: E. Hutton.
No. 3751

ETC-RE Label 1
1 Apr 67

FIGURE B-3



Photographed 4 months 11 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: CANAL ZONE

PIPERACEAE
Piper

Fort Clayton, old hospital area.
10' tall, many stemmed, plant bell-shaped.

Coll. Edwin L. Tyson & Kurt E. Blum.

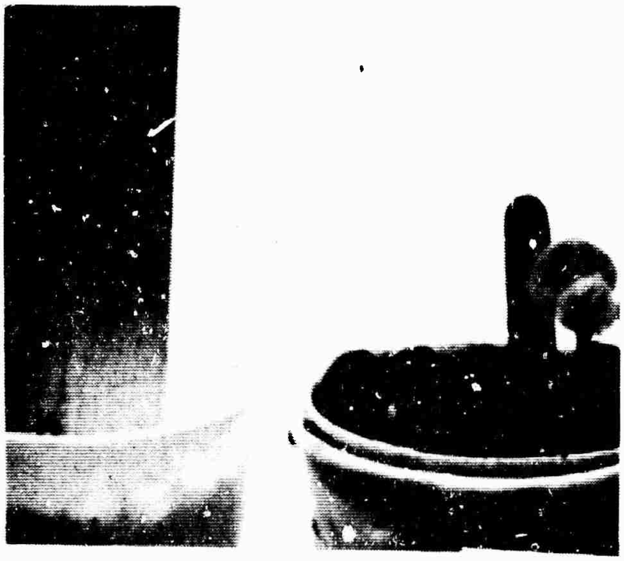
Det.

Seedling Photo: E. Hutton.

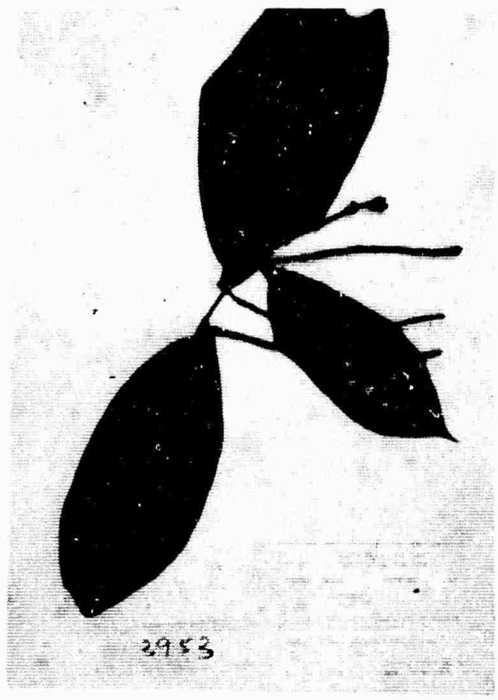
No. 3890

ETC-RE Label 1
1 Apr 67

FIGURE B-4



Photographed 3 months 29 days
after planting



US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: CANAL ZONE

PIPERACEAE

Piper.

12 miles S. Colon on Rio Providencia.
8' tall, forest shade.

Coll. Edwin L. Tyson & Kurt E. Blum.

Det.

Seedling Photo: E. Hutton.

No. 3953

ETC-RE Label 1
1 Apr 67

FIGURE B-5

Photographed 4 months 5 days after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: CANAL ZONE

ARACEAE

12 miles S. Colon on Rio Providencia.
3' tall, deep shade, fr. orange.

Coll. Edwin L. Tyson & Kurt E. Blum.

Det.

Seedling Photo: E. Hutton.

No. 3954

FIGURE B-6

Photographed 3 months 28 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: PANAMA

CLUSIACEAE

Clusia.

One mile S. El Valle, 2500' elevation.

15' tall, 3" dbh, fruit red-brown, sap milky.

Coll. Edwin L. Tyson, F.R. Fosberg et al.

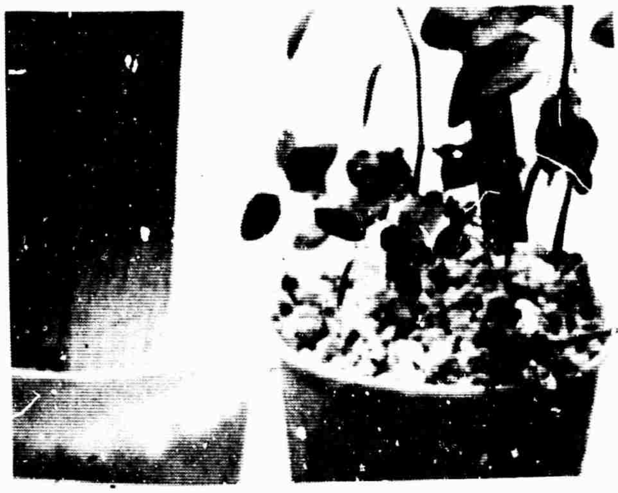
Det.

Seedling Photo: E. Hutton.

No. 3964

ETC-RE Label 1
1 Apr 67

FIGURE B-7



Photographed 3 months 16 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: CANAL ZONE
MORACEAE
Ficus obtusifolia HBK.

Curundu near gate to Panama City.
6J' tall, 20" dbh. Tree spreading from low (limbs.

Coll. Edwin L. Tyson.

Det.

Seedling Photo: E. Hutton.

No. 4018

ETC-RE Label 1
1 Apr 67

FIGURE B-8

Photographed 1 month 26 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: VERAGUAS
SAPINDACEAE
Allophylus Occidentalis (Sw.) Radkl.

5 miles E. Santiago.
Shrub 10' tall, fruit orange.

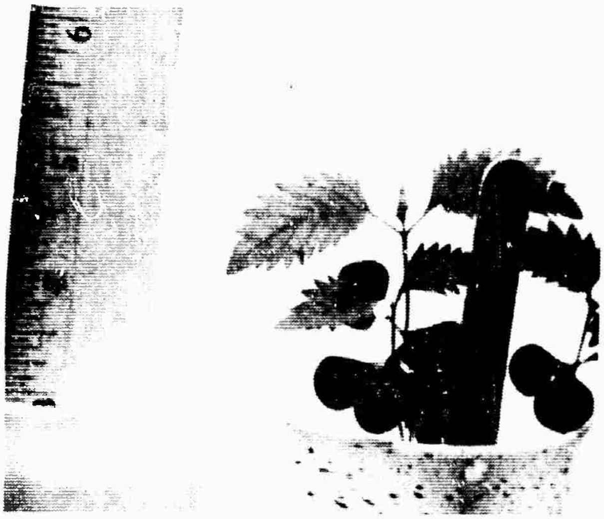
Coll. Edwin L. Tyson, C. Kupfer & H. Smith.

Det.

No. 4283 Seedling Photo: E. Hutton.

ETC-RE Label 1
1 Apr 67

FIGURE B-9



Photographed 1 month 26 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: CANAL ZONE

BIGNONIACEAE

Tabebuia.

Tree 35' tall; inflorescence yellow flowers
with corolla ; llow at base dull carmine red at
apex, fruits brown; Curundu Survival School
(Area.

Coll. Edwin L. Tyson, J.D. Dwyer.

Det.

Seedling Photo: E. Huttor.

No. 4456

ETC-RE Label 1
1 Apr 67

FIGURE B-10

Photographed 1 month 26 days
after planting

US ARMY TROPIC TEST CENTER
Fort Clayton, Canal Zone

COUNTRY: PANAMA PROVINCE: CANAL ZONE
ARACEAE

2' tall. Fruits bright red.
12 miles S. Colon.

Coll. Edwin L. Tyson, J.D. Dwyer & Kurt E. Blum.

Det.

Seedling Photo: E. Hutton.

No. 4486

ETC-RE Label 1
1 Apr 67

FIGURE B-11

- APPENDIX C -

VEGETATION INVENTORY*

An inventory of live shrubs and trees present in the Albrook Forest Observational Site (17PPV 602964) was prepared in June 1965. The inventory showed graphically the location of trees and shrubs within a square divided into 36 10-by 10-meter plots. The inventory was repeated in June 1966 and the revised tabulations were published as an appendix to Semi-annual Report # 1 and 2, Environmental Data Base for Regional Studies in the Humid Tropics, dated October 1966.

The format of this second revision of the inventory which was completed in January 1967 was changed and all entries consist of numbers arranged in tabular form. Location of trees and shrubs, girth at 120 cm. above ground, height to first branch, and overall height are all listed numerically under appropriate tabular headings. Trees are also grouped numerically, by reference to numbered drawings, into seven representative shapes. The change of format of the inventory enables accumulation of more information with equal or less effort and will permit machine analyses of accumulated data to reveal the occurrence of growth, emergence of new specimens, and other changes which take place with passage of time.

The first page of the inventory is a topographic map of the 60-by 60-meter grid of the observational area. Corners of the 36 10-by 10-meter plots within the area have letter-number designations to locate the position and orientation of the plot within the grid. Letters and numbers indicate north-south and east-west locations respectively.

Pages immediately following the map contain names of the more common species of trees found in the area. The approximate coverage of the high and middle canopies is indicated in the diagrams which follow the list of names. Each of the 36 tables which follow the diagrams contain information about one 10-by 10-meter plot. Each table is numbered to permit its identification within the grid area. For example, the first table G7G6F7F6 represents the upper left hand plot in the grid. Numbers in the "X-Y" column are keyed according to the scheme shown here (in which two trees from the first table, G7G6F7F6, are plotted).

The description of the Cecropia tree above is continued in succeeding columns of the referenced table. Shape III is in reference to the seven (I through VII) representative drawings found at the back of the inventory. DBH CM indicates diameter in centimeters at breast height (120 cm. above ground); height to first branch and height overall are given in meters.

Blanks were left in the tables for entry of information which can be

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* Prepared by Dr. Robert S. Hutton; Biological Scientist. Topographic map, canopy sketches, and list of trees are from second edition of Vegetation Inventory prepared by Hutton and Tyson.

obtained from the earlier inventory.

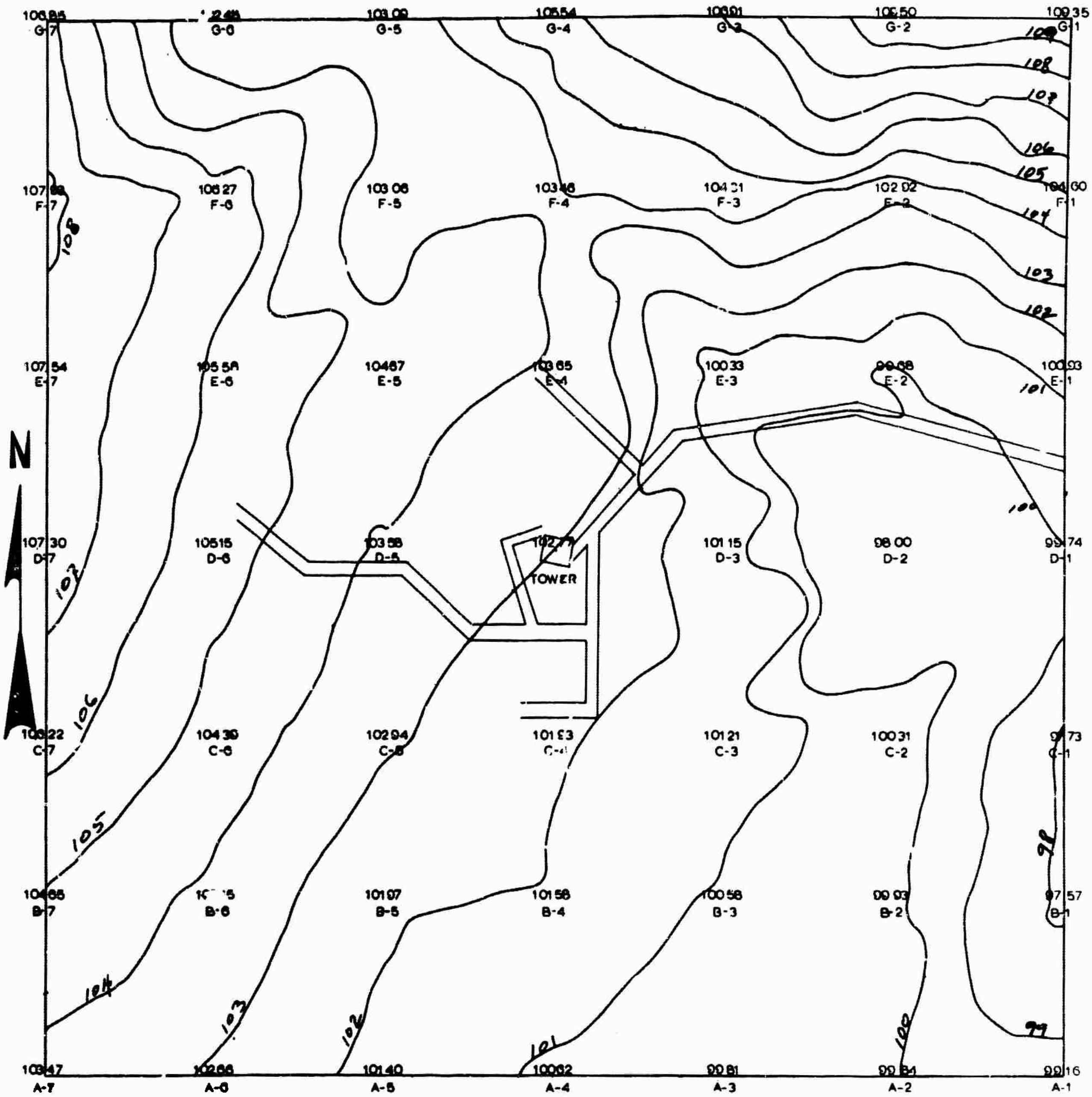
The Locator is intended to serve several purposes:

a. Copies are available for observers or visitors for use as required.

b. A master copy will be maintained to record notes concerning phenological events and corrections that are found necessary. Further revisions will be made as the need arises but will not necessarily be at regular intervals.

c. Copies will be provided to any investigator wishing to use the site to record location of points of interest and points that are not to be disturbed by other investigators.

Users are requested to furnish significant observations. Observations will be placed on the master copy as soon as received and will be included in revisions.



10 Meters

Grid Orientor
Grid Stake Locations
Ground Contours: 1 ft. interval
Elevation in feet

List of Trees and Small Trees over One Inch in Diameter.

Anacardium excelsum (Bert. + Balb.) Sheels. (Anacardiaceae)

Alibertia edulis (L. Rich) A. Rich (Rubiaceae)

Andira enermis H.B.K. (Fabaceae)

Annona (1) hayessii Suff. (Annonaceae)

Annona (2) purpurea Moc. + Sessi (Annonaceae)

Aphelandra deppeana Schlecht. + Cham (Acanthaceae)

Bactris balanoidea (Oerst.) Wndl. (Phoenicaceae)

Banara guianensis Aubl. (Flacortiaceae)

Belotia panamensis Pittier (Tiliaceae)

Bursera simaruba Sarg. (Burseraceae)

Cavanillesia platanifolia H.B.K. (Bombacaceae)

Cecropia (1) longipes Pittier ? (Moraceae)

Cecropia (2) obtusifolia Bertol. (Moraceae)

Cecropia (3) peltata L. (Moraceae)

Chrysophyllum cainito L. (Sapotaceae)

Conostegia speciosa (Melastomaceae)

Copaifera panamensis (Britton) Standley

Cordia alliodora (Ruiz + Pan) Roem + Schult (Boraginaceae)

Costus villosissimus Jacq. (Costaceae)

Croton panamensis (Klotzsch) Muell. Arg (Euphorbiaceae)

Cupania cinerea Poepp + Endll. (Sapindaceae)

Ficus aff. hemsleyana Standl.

Genipa caruta var americana (Rubiaceae)

Guazuma ulmifolia Lam. (Sterculiaceae)

Heliconia platystochys Baker. (Musaceae)

Helicteres guazumifolia H.B.K. (Sterculiaceae)

Hirtella (1) racemosa L. (Rosaceae)

Hirtella (2) triandra Swartz. (Rosaceae)

Inga (1) hayessii Bents. (Mimosaceae)

Inga (2) oerstediana Willd. (Mimosaceae)

Lacistema aggregatum (Berg.) Rusby (Lacistemaceae)

Lafoensia punicifolia DC. (Lythraceae)

Luehea seemanii Triana + Planch. (Tiliaceae)

Miconia (1) argentea (Swartz) Don. (Melastomaceae)

Miconia (2) impetrolaris (Swartz) DC. (Melastomaceae)

Nectandra sp. (Lauraceae)

Palicourea guianensis Aubl. (Rubiaceae)

Piper (1) aduncum L. (Piperaceae)

Piper (2) reticulatum L. (Piperaceae)

Phoebe costaricana Mez + Pittier (Lauraceae)

Pittoniotis trichantha Griseb (Rubiaceae)

Posequeria latifolia (Rudge) Roem + Schult. (Rubiaceae)

Rourea glibra H.B.K. (Connaraceae)

Sloanea sp. (Eleocarpaceae)

Spondias mombin L. (Anacardiaceae)

Tabebuia pêntaphylla (L.) Hemsl. (Bignoniaceae)

Talisia nervosa Radlk. (Sapindaceae)

Trema micrantha (L.) Blume (Ulmaceae)

Xylopia frutescens Aubl. (Annonaceae)

Identifying Numbers of Tagged Shrubs.

Alibertia edulis (L. Ridh.) A. Rich (Rabiaceae)

1785, 1789-1791, 1797-1800, 1882, 1884-B, 1885, 1887-1888, 1890-1892, 1894, 1898-1903, 1906-1907, 1912, 1914, 1921-1922, 1929, 1935, 2513.

Ardesia siebertii Lundel (Myrsinaceae)

1904

Conostegia speciosa Naud. (Melostomaceae)

1784, 1895

Hirtella racemosa Lam. (Amygdalaceae=Rosaceae)

1915, 2515, 2518

Ouratea wrightii (Van Tiegh.) Riley (Ochnaceae)

1874

Palicourea guianensis Aubl. (Rubiaceae)

1782, 1788, 1795, 1876, 1883, 1884, 1889, 1905, 1909-1911, 1930

Piper (1) adunctum L. (Piperaceae)

2512

Piper (2) nov. sp. (Piperaceae)

1920, 1933

Psychotria (1) cuspidata Bredem (Rubiaceae)

1786-1787, 1793, 1796, 1802, 1877-1879, 1919, 1922-B, 1923, 1925-1928, 1931, 1934

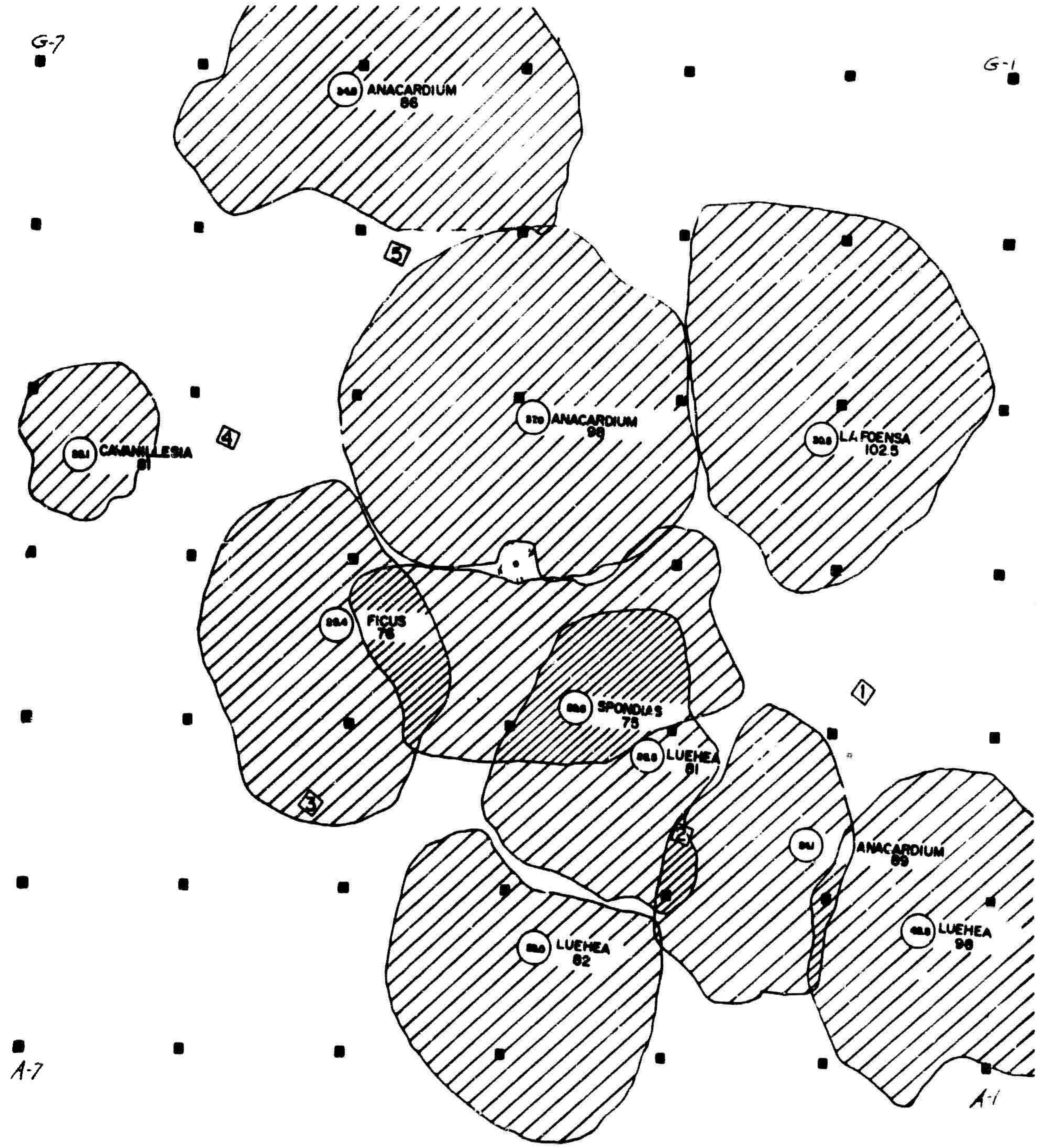
Psychotria (2) horizontalis Swartz (Rubiaceae)

1780, 1801

Psychotria (3) undata Benth. (Rubiaceae)

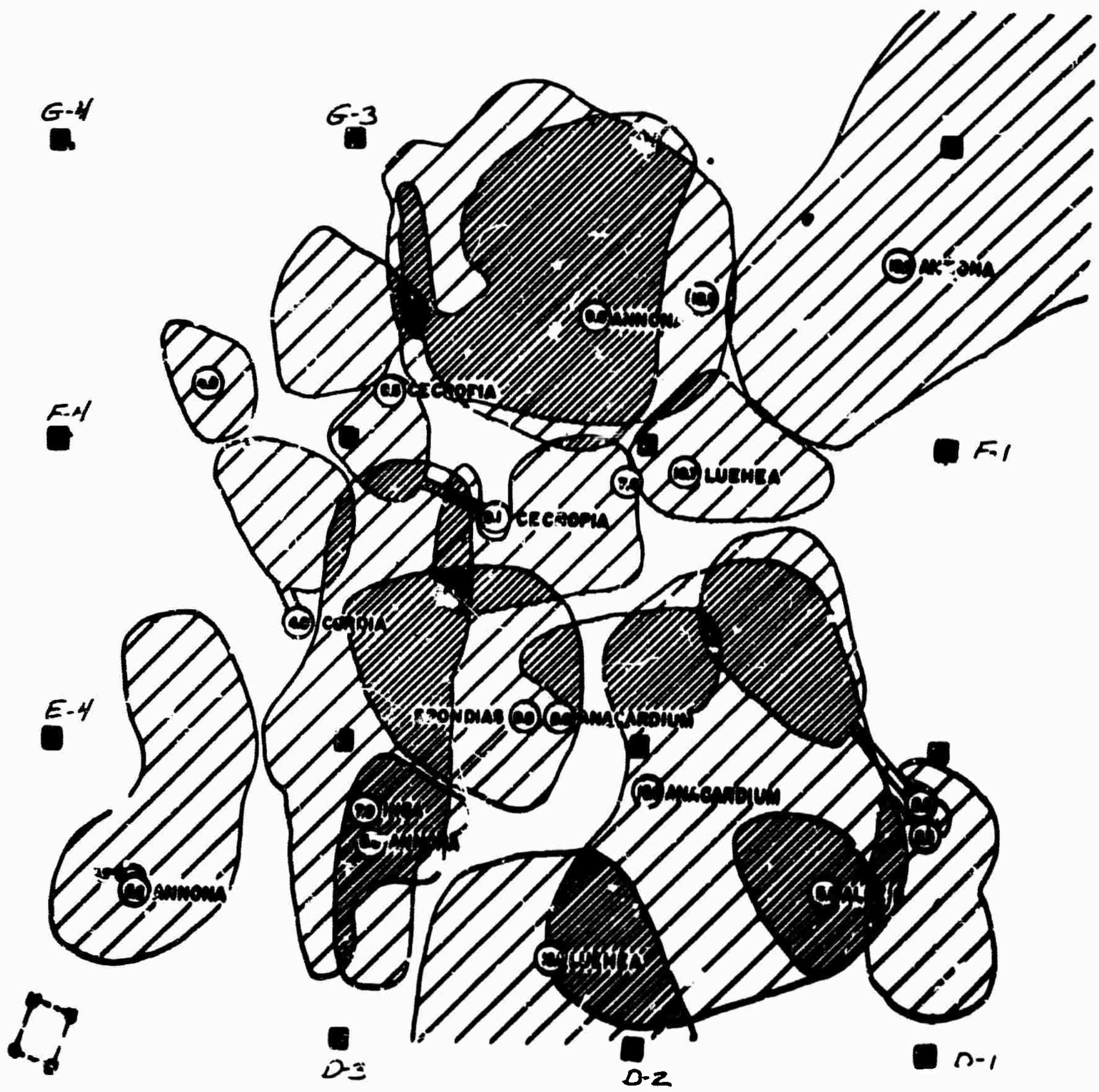
1783, 1792, 1875, 1881, 1886, 1893, 1913, 1916-1918, 2514, 2516

UPPER CANOPY COVERAGE



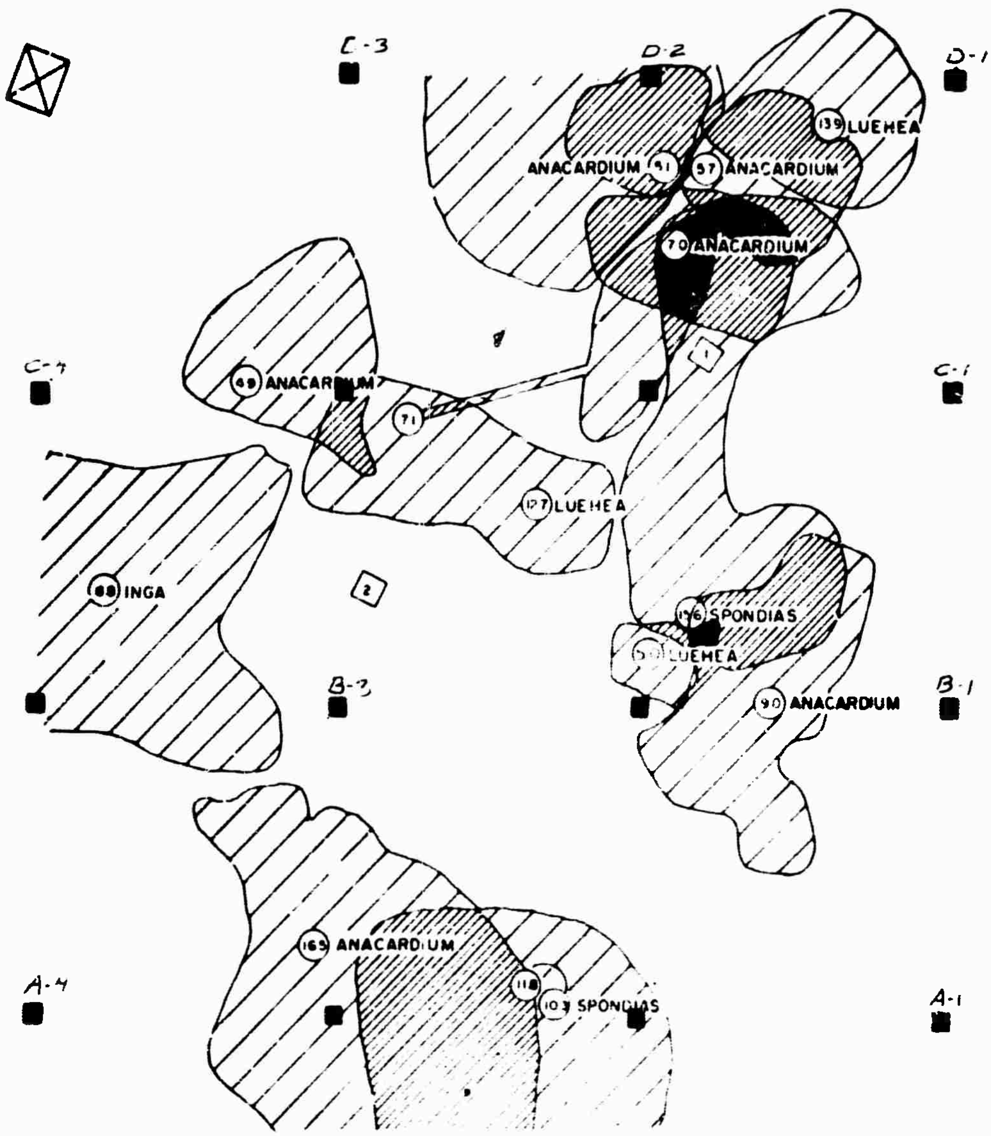
LOWER CANOPY COVERAGE

NE Quadrant



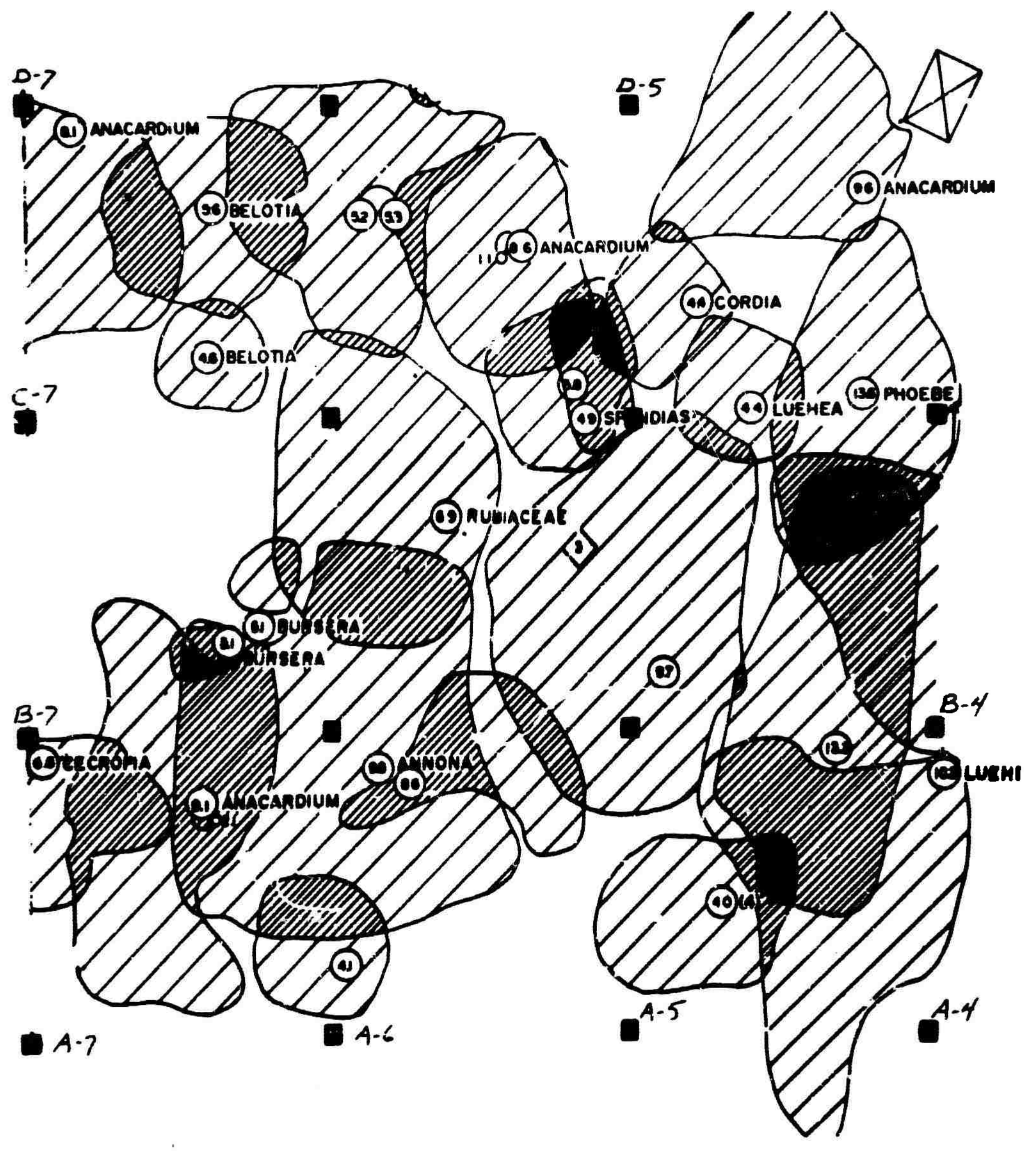
LOWER CANOPY COVERAGE

SE Quadrant



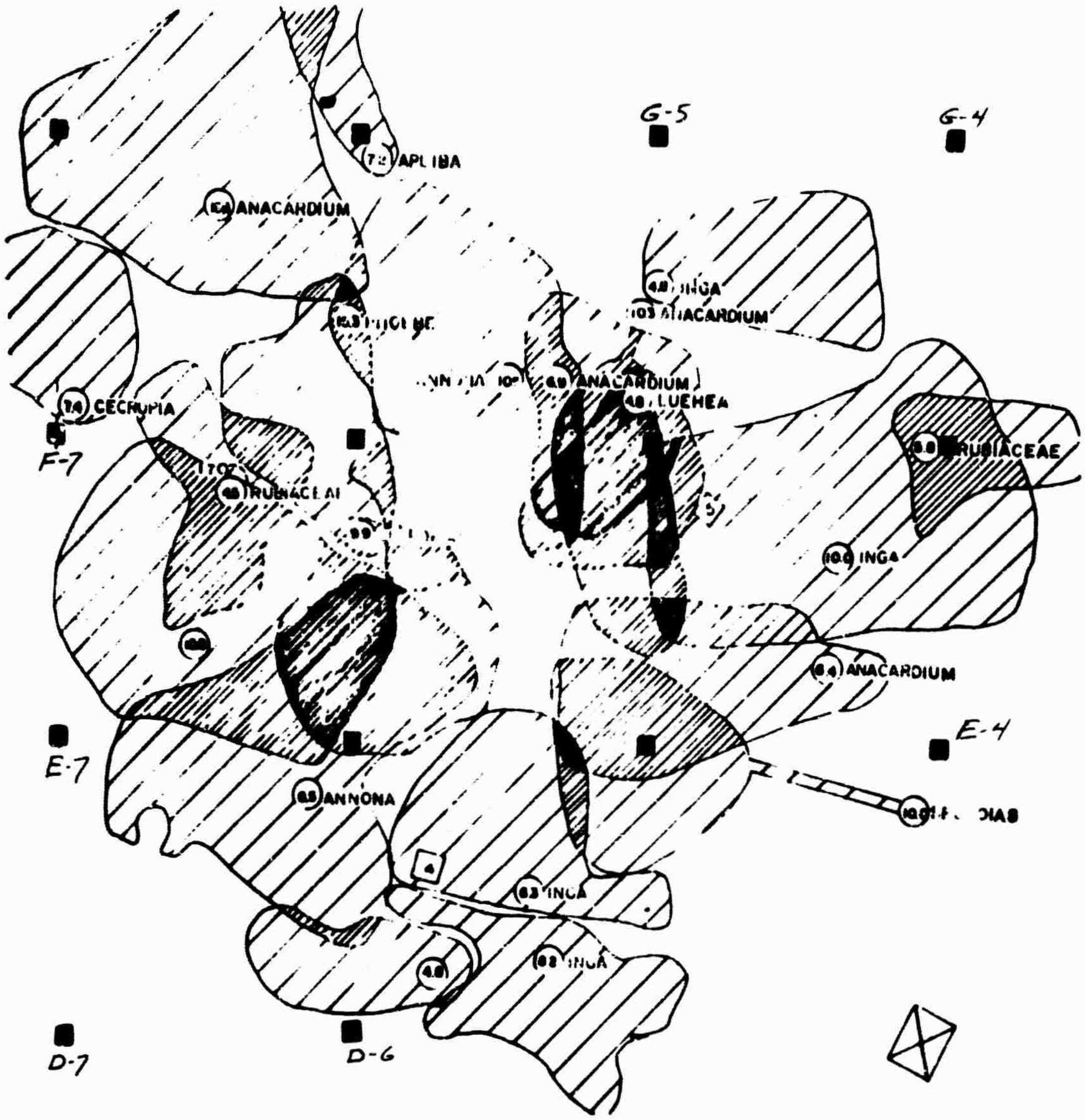
LOWER CANOPY COVERAGE

SW Quadrant



LOWER CANOPY COVERAGE

NW Quadrant



G7 G6 F7 F6 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	1	Cecropia	III	18.8	20	-	12.5	-	16.	
0	3	Belotia	III	3.3	5.5	-	2.8	-	6	
1	3	Croton								Chopped Dead
2	1		II	3.3						Dead
2	3									Chopped Dead
3	3		V	3.5	3.7	-	2.0	-	4.2	
3	7		I	4.6	4.8	-	2.5	-	3.6	
4	2	Croton	IV	2.54	2.7	-	1.2	-	4.5	
5	7	Anacardium	I	4	4.0	-	8	-	20	
9	4	Phoebe	III	3.8	4.4	-	3.9	-	5.4	
9	4	Phoebe	I	38.8	41.6	-	2.9	-	22	

G6 G5 F6 F5 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	8	Tabebuia	I	4.8	5.0	-	2.5	-	3.9	
1	9	Guazuma	IV	18.3	19.0	-	8	-	16.5	
3	7	Anacardium	I	7.6	8.4	-	3	-	6.9	
5	2	Annona	I	24.5	27.2	-	5.4	-	20.5	
6	2	Anacardium	I	17.5	17.5	-	3.6	-	15	
6	7	Sapindaceae	I	9.5	9.5	-	3.6	-	9	
6	8	Anacardium	I	6.04	6.3	-	3	-	6.6	
8	5		I	4	4	-	1.5	-	2.7	
9	1	Luehea	I	12.2	12.3	-	3.9	-	11	
9	8	Anacardium	I	88.3	86.7	-	10	-	33.5	

G5 G4				D B H C M		FIRST BRANCH M		HEIGHT M		
F5 F4		SPECIES	SHAPE							REMARKS
X	Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
0	4	Anacardium	I	25.8	25.8	-	1.2	-	3.3	
0	5	Inga	I							Dead
0	7		VII	3.0	3.1	-	3.6	-	4.5	
0	7		VII	M	3.7	-	3	-	5.7	
0	8		VII	3.7	3.7	-	3.6	-	4.5	
1	8		VII	4.1	5	-	5.4	-	6.4	
1	8		VII	3.8	4.4	-	3.9	-	6	
1	8		VII	3.4	3.4	-	4.5	-	5.7	
1	9		VII	3.1	3.1	-	4.8	-	6	
2	7		VII	3.1	3.1	-	1.5	-	2.8	
2	7		VII	3.7	3.7	-	4.3	-	4.5	
2	8		VII	3.1	3.1	-	4.5	-	5.7	
2	8		VII	3.4	3.4	-	4.8	-	6	
2	8		VII	3.7	3.7	-	4.8	-	6	
2	8		VII	3.5	3.7	-	3.3	-	4.8	
2	9		VII	3.1	3.1	-	4.5	-	5.7	
3	2	Pittonoitis	I	5.3	5.6	-	1.8	-	4.8	
3	7		VII	3.7	3.7	-	1.2	-	3	
3	8		VII	3.7	3.7	-	.8	-	2.8	
3	9		VII	2.7	2.7	-	4.2	-	5.7	
3	8		VII	3.7	3.7	-	4.8	-	6	
3	8		VII	4	4	-	2.8	-	4.5	
3	9		VII	3.3	3.7	-	4.5	-	5.4	
3	9		VII	3.8	4.7	-	5.4	-	6.4	
4	9		VII	3.0	3.7	-	1.8	-	3.6	
5	1		IV	*	2.4	-	.8	-	2.0	
6	1	Cupania	III	4.1	4.1	-	2.5	-	4.5	
6	2	Posequeria	IV	*	3.5	-	.4	-	2.8	
6	7		V	4	4	-	1.5	-	3.9	
6	7		V	3	3	-	1.8	-	1.8	Dead
6	8		V	3.4	3.4	-	1.8	-	4.2	
7	5		V	2.5	2.5	-	1.2	-	2.0	
7	5		V	Dead						Missing
7	7		V	3.0	3.2	-	1.5	-	1.5	
7	7		V	3.5	4	-	2.1	-	4.5	

G5 G4 F5 F4 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
7	7		V	4.3	4.6	-	2.1	-	4.5	
7	7		V	4	4	-	2.1	-	4.5	
7	8		V	4.2	4.2	-	1.9	-	4.5	
7	8		V	4	4	-	2.0	-	4.8	
7	8		V	4	4	-	2.1	-	4.5	
7	9		V	3.7	3.7	-	2.0	-	4.5	
9	1	Pittonoitis	I	14.7	14.7	-	2.0	-	7.6	

G4 F4 X	G3 F3 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS
1	7		III	M	2.6	-	.5	-	1.8	
1	8		V	3.5	4.7	-	2.5	-	3.6	
1	9		V	4.1	4.7	-	2.1	-	4.8	
1	9		V	M	4.2	-	1.8	-	5.1	
2	2			M						Missing
2	8	Croton	III	3.5	4.8	-	5.7	-	6.9	
2	8		V	4.1	4.1	-	2.0	-	5.4	
3	2			M						Missing
3	4		III	M	2.5	-	1.2	-	2.8	
3	6	Flacourtiaceae	III	4.3	6.2	-	3.6	-	6.6	
4	5		V	3.8	4.7	-	1.5	-	5.4	
4	6		V							Dead
4	6		V	M	3.0	-	1.8	-	3.3	
4	8	Ficus	III	3.8	4.5	-	2.8	-	4.5	
5	0	Flacourtiaceae	IV	2.3	3.2	-	1.2	-	4.5	
5	0	Banara	I	5.1	5.1	-	2.8	-	5.4	
5	4	Cordia	III	3.2	3.2	-	1.8	-	4.8	
5	4		V	M	4	-	1.8	-	3.9	
5	5		V	M	2.4	-	1.5	-	3.6	
5	5		V	M	4.5	-	3	-	5.7	
5	6		V	3.7	3.7	-	2.0	-	3.9	
5	7		III	M	3.3	-	2.8	-	4.5	
5	9		V	M	3	-	2.1	-	4.8	
5	9		V	3.3	4	-	2.1	-	5.1	
6	0		III	M	3.7	-	4.5	-	4.5	
7	1			M						Missing
7	4		I		6.0	-	.9	-	2.5	Chopped but living
7	9		I	M	3.4	-	3	-	6.4	
8	8	Cordia	I	2.5	5.6	-	2.5	-	4.2	
9	8		II	M	2.0	-	.8	-	3.6	

G3	G2	SPECIES	SHAPE	D B M C M		FIRST BRANCH M		HEIGHT M		REMARKS
F3	F2			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
X	Y									
0	0	Helicteres	II	2.5	3.0	-		-	2.5	
0	5		IV	M	3.6	-	.8	-	2.3	
0	7		III	M	2.2	-	1.8	-	2.8	
0	9		I	M	4	-	.7	-	6	
1	1	Cecropia	III	13.9	15.1	-	13.5	-	18.5	
1	7	Palicourea	I	7.8	9.5	-	1.2	-	6	
2	5	Annonaceae	III	8.3	9.5	-	5	-	15	
2	9		III	2.5	5.6	-	1.2	-	7.6	
3	1	Posequeria	II	3.5	4.6	-	1.8	-	3	
3	2		VII	5	5	-	1.2	-	2.8	
3	2		VII	M	4.7	-	3.6	-	5.4	
4	1		VII	3.4	3.4	-	5.1	-	6	
4	1		VII	3.7	3.7	-	2.5	-	5.4	
4	2		VII	3.7	3.7	-	.8	-	3.3	
4	2		VII	4.6	4.7	-	1.8	-	4.2	
4	9	Miconia	II	2.5	3.7	-	.3	-	4.2	
4	9		II	M	2.7	-		-	2.5	
5	0		VII	M	5	-	1.2	-	3.6	
5	0		VII	M	4.4	-	2.8	-	3.6	
5	0		VII	M	3.4	-	4.5	-	4.5	
5	1		VII		2.1	-	1.8	-	2.7	
5	8	Miconia	I	2.8	2.8	-	1.8	-	3.9	
6	0		VII	M	3.7	-	4.5	-	6	
6	0		VII	M	4.4	-	6	-	7.6	
6	4	Hirtella	II	3.3	4	-		-	3.6	
7	0		VII	M	4.4	-	4.2	-	6	
7	3	Annona	I	22.2	22.2	-	6	-	10	
7	9		I	M	1.9	-	1.2	-	4.2	
7	9	Psychotria	IV	*	2.	-	1.8	-	3.6	
8	0		VII	M	4.4	-	1.5	-	3	
8	8	Piper	III	*	2.6	-	1.8	-	3.6	
9	9		I	M	2.2	-	1.5	-	2.8	

G2 G1 F2 F1 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	9		I	M	2.0	-	1.2	-	3	
1	2		I	M	2.3	-	1.5	-	3.9	
2	1		I	M	2.6	-	.8	-	3.6	
2	4		I	46.9	50.3	-	13	-	23	
2	7	Miconia	III	3.5	3.6	-	5.1	-	6.3	
2	7			M		-		-		Missing or chopped
2	9		I	M	2.0	-	.8	-	3.3	
4	8	Miconia	I	7.1	7.8	-	4.8	-	7.6	
7	3	Posequeria	III	4.8	5.0	-	2.8	-	4.5	
7	7	Chrysopallum	I	2.5	3	-	1.8	-	4.5	
8	3		III	5.1	8.4	-	3.6	-	6	
8	5	Annona	I	29.9	29.9	-	8	-	15	

F7 F6 / E7 E6 / X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS
0	4		II	M	4.4	-	.9	-	.9	Chopped or missing
0	5	Nectanda	I	2.8	2.8	-	1.2	-	3.9	
1	1	Anacardium	I	3.8	4.4	-	2.0	-	5.4	
1	7	Hirtella	I							Dead
1	9	Croton	IV	3.5	4.1	-	.5	-	3.6	
2	0		V	M	4.5	-	1.2	-	2.0	
2	8		III	M	2.3	-	2.5	-	3	
3	0	Rubiaceae	III	5.3	6.2	-	3.9	-	6.4	
3	3	Sapindaceae	I	27.4	28.5	-	2.5	-	20	
3	7	Posequeria	III	3.5	5.0	-	2.0	-	4.5	
5	2	Anacardium	I	4.8	5	-	2.0	-	3.3	
5	8	Pittoniotis	I	11.3	11.7	-	1.7	-	10	
5	9	Pittoniotis	I	4.3	5.3	-	1.7	-	3.9	
6	3		I	8.5	9.6	-	1.9	-	9	
9	7	Cecropia	III	24.4	24.4	-	23	-	32	
9	8		IV	M	2.5	-	.8	-	2.5	

F6 F5 E6 E5 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
1	7	Andira	II	4.6	4.9	-	.5	-	7.6	
1	7		II	7.8	8.2	-	.5	-	7.6	
1	7		II	5.8	6.3	-	.5	-	7.6	
2	3			M	2.6	-	1.2	-	1.2	
2	7	Andira	II	2.5	3.0	-	.5	-	7.6	
2	7		II	3.8	4.1	-	.5	-	7.6	
3	5		III							Was dying
3	5		IV	M	3.4	-	.8	-	3.6	
3	0	Belotia	III	2.5	4.7	-	4.2	-	6	
4	6		I	M	2.4	-	1.5	-	2.5	
6	3	Copaifera	III	4.1	4.7	-	5.4	-	6.9	
6	5		IV	2.8	2.8	-	.7	-	4.2	
6	6		I	M	2.4	-	.8	-	3.3	
7	2	Spondias	I	3.0	3.6	-	2.8	-	4.8	
7	5		V	M	2.8	-	2.0	-	3	
7	5		V	M	4.1	-	2.0	-	3.9	
7	5		V	M	4.4	-	2.8	-	6	
7	5		V	M	4.0	-	2.8	-	5.4	
8	5		I	M	3.0	-	1.2	-	3	
9	8	Nectandra	II	4.2	4.2	-		-	3.9	

F5 F4			D B H C M		FIRST BRANCH M		HEIGHT M		
E5 E4	SPECIES	SHAPE							REMARKS
X Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
1 6	Luemea	II	4.6	5.4	-	1.8	-	2.8	
1 6		II	3.5	4.6	-	2.8	-	4.8	
2 8	Ficus	I	6.0	6.3	-	2.8	-	4.5	
4 6	Pasequeria	I	5.1	5.4	-	1.8	-	4.5	
6 3	Anacardium	I	16.2	17.5	-	4.5	-	19	
6 6	Inga	I	22.4	22.4	-	2.8	-	13.5	
8 9		I	M	15.1	-	1.8	-	11	

F4 F3 E4 E3 X Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
1 4		III	M	2.6	-	.8	-	3	
2 0		VII	M	1.8	-	.8	-	2.8	
2 0		VII	M	1.8	-	.8	-	3.6	
3 6	Flacourtiaceae	I	5.6	6.3	-	1.8	-	6.9	
6 9	Cecropia	III	2.5	3.7	-	6	-	6	
8 2		III	*	2.0	-	1.5	-	2.5	
8 3	Cordia	III	10.1	12.4	-	6.5	-	12.5	
8 6		I	M	2.4	-	1.5	-	4.5	
9 8		I	M	3	-	1.9	-	6	

F3 E3 X	F2 E2 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS
0	5	Luehea	I	6.8	7	-	2.5	-	7.6	
1	3	Anacardium	IV	8.0	8.4	-	1.9	-	6.5	
2	5	Anacardium	I	6.6	9.4	-	2.0	-	6	
2	5	Anacardium	I	9.3	11.3	-	2.8	-	5.5	
4	9		VII	M	4.4	-	1.8	-	3.3	
4	9		VII	M	3.7	-	1.5	-	2.8	
4	9		VII	M	3.7	-	.8	-	2.5	
5	6	Cecropia	III	22.6	22.6	-	20	-	25	
5	9		VII	3.8	4.4	-	3.3	-	5.4	
6	0	Spondias	I	2.5	25	-	3.9	-	14.5	
6	4		I	M	3.0	-	1.3	-	3	
6	5		I	M	3.6	-	1.8	-	3.3	
6	9		VII	4.3	4.4	-	.8	-	3.9	
7	0	Anacardium	I	11.3	11.3	-	3.9	-	16.5	
9	7		I	19.3	19.6	-	11	-	5.1	

F2 E2 X	F1 E1 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	 1 Jan 1967	HEIGHT M 4 Jun 1967	 1 Jan 1967	REMARKS
1	8	Luehea	III							Dead
2	1		I	2.2	2.2	-	1.5	-	3.9	
4	5		IV	M	2.2	-	.3	-	3.6	
5	5		VII	5.1	*5.10	-	.9	-	2.8	
5	5		VII	M	1.4	-	2.8	-	3.6	
5	1	Anacardium	I	6.6	6.6	-	3.3	-	6.6	
5	6		VII	M	1.0	-	2.0	-	3.6	
6	1		I	M	4.4	-	1.2	-	4.2	
7	6	Piper	III	2.8	3.0	-	3.3	-	5.4	
8	1	Alibertia	II	4.1	5	-		-	6	
8	7	Chrysophylum	I	4.6	4.8	-	3	-	6	

E7 E6				D E H C M		FIRST BRANCH M		HEIGHT M		
D7	D6	SPECIES	SHAPE	1 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	REMARKS
X	Y									
1	0	Belotia	III	3.5	4.9	-	4.5	-	6.5	
1	5		V	3.5	3.6	-	1.8	-	3.5	
1	5		V	3.5	4	-	2.0	-	3.5	
1	5		V	Dead	3.6	-	3.3	-	3.3	Dead
1	5		V	3.1	3.1	-	1.8	-	3.6	
1	6		V	2.3	2.3	-	1.5	-	2.7	
2	5		V	Dead	3.4	-	1.8	-	3	Dead
2	6		V	3.7	3.7	-	2.0	-	4.2	
2	6		V	Dead	3.4	-	2.0	-	2 [illegible]	Dead
3	1	Belotia	III	4.6	6.7	-	3	-	8.4	
3	2		I	M	2	-	1.5	-	4.2	
3	7	Cavanillesia	VI	66.3	70.1	-	18	-	24	
3	7	Cecropia	I	7.6	10.1	-	10	-	15	
4	4		V	Dead	3.6	-	1.5	-	3.3	Dead
4	4		V	4.1		-	1.2	-	1.2	
4	4		V	3.2	3.2	-	1.5	-	3.3	
5	0	Belotia	III	4.1	5.7	-	3.5	-	7.2	
5	3	Cecropia	III	5.1	9.5	-	14	-	14.5	
5	3	Belotia	III	2.5	3.2	-	4.5	-	6.0	
6	4	Croton	III	2.1	3	-	2.0	-	5.6	
8	8	Annona	I	12.3	12.3	-	4.4	-	16.5	
3	8			M						Missing

E6 E5			D B H C M		FIRST BRANCH M		HEIGHT M		
D6 D5	SPECIES	SHAPE							REMARKS
X Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
0 8		II	M	3.6	-	.5	-	2	
1 8		VII							Dead
2 3	Annonaceae	I	12.1	12.1	-	8	-	16.5	
4 9		V	M	3.0	-	1	-	3.5	
5 9		V	M	3.0	-	1	-	3.5	
6 3	Inga	I	19	19	-	8	-	12	
6 5	Inga	I	16	16.1	-	3.5	-	13	
9 4	Luehea	I	5.1	7	-	1	-	5.5	

E5 E4 D5 D4 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	8	Posequeria	I	2.5	5.6	-	1.3	-	4.5	
1	4		I	M	7.8	-	1	-	4.5	
3	5			Dead	9.7	-	2	-	2.5	Dead
4	5		IV	M	2.0	-	1	-	2.5	
5	0		VII	M	3.7	-	1	-	3	
5	1		VII	3.0	3.1	-	1	-	2.5	
5	2		VII	M	3.1	-	3.5	-	4.5	
5	2		VII	3.7	3.7	-	3.5	-	5	
5	2		VII	5	5	-	4.3	-	1	
5	3		VII	4.4	4.4	-	1.3	-	2.5	
5	3		VII	M	4	-	4.5	-	6	
6	3		VII	2.7	2.7	-	1	-	2	
6	3		VII	M	2.8	-	2.5	-	4.5	
6	3		VII	3.7	3.7	-	3.5	-	5.5	
6	4		VII	M	2.5	-	1	-	2	
7	7		I		2.8	-	1	-	3	
8	5	Hirtella	I	2.2	2.2	-	2	-	3.5	
9	7	Spondias	III	2.5	25	-	11	-	15	

E4 E3			D B H C M		FIRST BRANCH M		HEIGHT M		
D4 D3		SPECIES	SHAPE						REMARKS
X	Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
0	2		III	M	2	-	3	-	3.5	
0	3		III	M	2.6	-	3.7	-	40	
0	9	Anacardium	I	93.2	98.0	-	4.3	-	30	
0	9		II	M	2	-		-	3	
1	5		III	M	4	-	3.5	-	4.5	
3	5	Annona	IV	15.7	17.7	-	4.0	-	7	
3	5	Annona	IV	9.3	9.3	-	3	-	5.3	
3	7	Alibertia	III	*	3.7	-	2.5	-	5.0	
3	6		IV	M	2.3	-	1	-	2.5	
4	2	Palicourea	I	*	2.8	-	1	-	2.5	
4	4		I	M	2.5	-	1	-	3	
5	7	Posequeria								Dead or Chopped
7	6	Palicourea	IV	*	1.8	-	1	-	2.5	
8	1	Annona	I	3.0	3.4	-	3	-	4.5	
8	3	Anacardium	I	3.0	3.1	-	1	-	3	

E3	E2	SPECIES	SHAPE	D B H C M		FIRST BRANCH M		HEIGHT M		REMARKS
D3	D2			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
X	Y									
0	7	Inga	I	17.8	21.0	-	5.4	-	14	
1	6	Annona	I	19.0	19.0	-	4.5	-	16	
5	1		VII	M	3.4	-	3.6	-	4.2	
5	2		VII	3	3.7	-	6.4	-	7.2	
5	2		VII	2.8	3.7	-	3.9	-	4.5	
5	2		VII	4	4	-	3.6	-	5.4	
5	2		VII	3.8	4	-	4.5	-	6	
5	2		VII	3.5	4	-	1.2	-	3.6	
6	1		VII	M	3.7	-	3.9	-	5.4	
6	2		VII	3.0	3.1	-	6	-	7.6	
6	2		VII	3.3	3.7	-	5.4	-	6.6	
6	3		VII	3.3	3.4	-	6	-	6.9	
6	3		VII	3.3	3.7	-	6	-	7.2	
6	3		VII	3.1	3.1	-	5.7	-	6.9	
6	3		VII	4.4	4.4	-	4.8	-	6	
6	3		VII	3.5	3.7	-	6	-	6.9	
6	3		II	4.6	5.5	-	4.5	-	6	
6	4		VII	5	5	-	1.2	-	3.6	
7	2		VII	3.0	3.1	-	4.5	-	6	
7	3	Luehea	III	42.9	43.2	-	13	-	23	
8	8	Lafoensia	I	77.4	78.4	-	11	-	36	
9	6									Not Inside

D7 D6				D B H C M		FIRST BRANCH M		HEIGHT M		
C7 C6		SPECIES	SHAPE							REMARKS
X	Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
1	3	Nectandra	II	2.6	2.6	-		-	3.6	
1	4	Hirtella	II	3.4	3.4	-		-	3.9	
1	9	Anacardium	I	20.4	20.8	-	8.5	-	10	
3	0		II	M	1.8	-		-	2.8	
3	3	Nectandra	I	4.1	4.8	-	3.6	-	5.4	
3	3									Dead or dying
4	0	Hirtella	II	2.5	3.0	-		-	3.9	
4	5	Conostegia	II	2.8	3	-	2.8	-	4.2	
5	1	Belotia	III	10.1	10.1	-	6	-	12	
5	2		I	M	1.8	-	3.3	-	6	
5	6	Belotia	III	14.2	18.9	-	6.5	-	12	
5	6	Conostegia	I	*	1.8	-	.4	-	1.8	
7	0	Croton								Dead or dying
8	3	Andira	I	8.8	9.4	-	4.5	-	6.9	
8	3		I	2.5	3.2	-	2.8	-	3.6	

E2 E1 D2 X	D1 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS
0	6		III	*	5.5	-	5.4	-	6.6	
0	8	Anacardium	I	32.1	32.1	-	4.5	-	36	
1	2		VII	3.5	4.4	-	4.5	-	6	
1	3			Dead						Dead
1	3			Dead						Dead
1	0			3.5						Missing
1	6		VII	M	3.1	-	.5	-	1.8	
1	9	Chrysophyllum	I	*	2.3	-	.8	-	3.9	
2	2			Dead						Dead
2	5		VII	M	2.7	-	4.2	-	6	
2	7		VII	M	3.7	-	5.1	-	5.1	
2	7		VII	M	3.7	-	1.5	-	2.0	
2	7		VII	M	3.1	-	5.7	-	5.7	
3	1		VII	2.5	2.7	-	1.8	-	3.6	
3	1		VII	3.7	3.7	-	4.2	-	5.4	
3	1		VII		3.1	-	4.2	-	4.5	
3	2		VII							Dead
3	2		VII	3.7	3.7	-	4.2	-	6	
3	3		VII	3.0	3.4	-	6	-	7.6	
3	7		VII	M	3.4	-	.7	-	3.6	
3	8		VII	M	3.7	-	3.9	-	6	
4	1		VII	3.7	3.7	-	5.1	-	6	
4	7		VII	M	3.1	-	.5	-	3.6	
4	8		I	*	2.3	-	.5	-	3.6	
5	0		VII	3.7	3.7	-	1.7	-	3.6	
5	1									Missing
5	2		I	M	28.4	-		-	4.5	
5	5		VII	M	2.7	-		-	1.5	
5	5		VII	M	3.4	-	.8	-	1.8	
5	6		VII	M	3.1	-	.5	-	1.8	
5	6		VII	M	3.7	-	.7	-	1.8	
6	0		VII	3.7	3.7	-	3.9	-	4.5	
6	1		VII	3.0	3.7	-	4.2	-	5.7	
6	1		VII	4.1	4.4	-	6	-	8.2	
6	5	Genipa	III	14.2	14.3	-	4.2	-	17.5	
7	1		VII	4.1	5	-	2.8	-	4.2	
8	6		IV	M	1.9	-	.3	-	1.8	
9	4		IV	M	3.6	-	.4	-	4.2	
9	5	Annona	I	6.0	6.2	-	1.2	-	6	
9	6		I	Dying						Chopped
9	7		III	20.9	21.0	-	13	-	17.5	
9	7		III	21.7	22.0	-	12	-	21.5	
9	7	Annona	I	M	1.8	-	.5	-	.8	

D6 D5 C6 C5 X	 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	 1 Jan 1967	HEIGHT M 4 Jun 1967	 1 Jan 1967	REMARKS.
0	0	Copaifera	III	5.5	5.8	-	2.8	-	6	
0	6		I	13.1	13.1	-	7	-	10	
0	7		III	M	2.4	-	3.3	-	5.7	
1	6		I	13.4	13.5	-	8	-	11	
5	5	Anacardium	I	21.7	23.2	-	3.6	-	12.5	
7	1	Sapindaceae	I	14.7	15.1	-	7	-	12.5	
7	7		III	6.0	6.0	-	5.4	-	6	
8	0	Spondias	I	12.1	12.1	-	6	-	9.5	
8	5	Ficus	I	64.4	71.3	-	6.4	-	26.5	

D5 D4 C5 C4 X	 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	 1 Jan 1967	HEIGHT M 4 Jun 1967	 1 Jan 1967	REMARKS
1	1	Croton								Dead or dying
1	4	Palicourea	I	*	3.0	-	1.2	-	4.5	
2	3	Cordia	III	10.9	10.9	-	10	-	14	
2	6	Alibertia	I	*	2.6	-	1.8	-	3.3	
3	3		I	*	2.7	-	1.2	-	3.3	
3	4	Ardesia	I	2.5	3.0	-	.8	-	1.8	
5	5		VII	3.7	3.7	-	1.8	-	4.2	
5	7	Alibertia	I	*	2.8	-	1.5	-	2.8	
6	6		VII	M	3.4	-	1.8	-	3.6	
6	6		VII	3.7	3.7	-	.8	-	2.8	
7	0	Phoebe	I	34.5	35.1	-	11.5	-	26.0	
7	6	Anacardium	I	19.0	19.0	-	6	-	20.5	
8	6	Inga	I	9.8	9.9	-	6	-	12	
8	6	Inga	I	7.6	8.2	-	6	-	10	
9	2	Chrysophyllum	I	6.6	6.8	-	3.3	-	6.9	

D4 D3 / C4 C3 / X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	0	Lauraceae	IV		3.1	-	.8	-	3.9	
0	3	Alibertia	I	*	2.4	-	1.2	-	3.9	
3	7	Chrusophyllum	I	2.8	3.0	-	1.5	-	4.2	
3	8	Spondias	I	M	64.8	-	14	-	26.5	
3	8		VII	3.0	3.4	-	4.2	-	5.4	
3	8		VII	4.4	4.4	-	2.8	-	4.5	
3	9		I	*	2.6	-	2.5	-	3.9	
6	0	Anacardium	I	12.3	12.9	-	4.2	-	4.2	
6	0	Copaifera	I	7.6	8.0	-	4.5	-	6.9	
8	2	Annona	I	3.0	3.4	-	2.5	-	4.2	
8	8		VII	2.5	2.5	-	3	-	3	
8	8		VII	3.1	3.1	-	2.5	-	2.5	
8	8		VII	3.5	3.7	-	3.3	-	4.5	
8	8		VII	M	3.1	-	2.8	-	3.6	
9	4		I	3	3	-	2.8	-	4.8	

D3 C3 X	D2 C2 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS Dead or Chopped
1	7	Psychotria	VII	5	5	-	3.6	-	5.1	
2	0		VII	2.5	2.5	-	1.2	-	3.3	
2	0		I	4.5	4.5	-	1.5	-	4.2	
2	0	Apocynaceae	I	M	2.8	-	.3	-	.8	
2	2		VII	2.5	2.5	-	.3	-	3.6	
3	0		VII	3.1	3.1	-	3.6	-	4.2	
3	0		VII	M	2.5	-	3.6	-	4.2	
3	0		VII	M	2.5	-	1.2	-	3.3	
3	0		II	*	2.0	-	.8	-	2.8	
3	6	Alibertia	VII	4.3	4.4	-	3.9	-	5.7	
3	8		VII	3.7	3.7	-	3.6	-	4.5	
3	8		VII	4.6	5	-	4.5	-	6.4	
3	8		VII	3.1	3.1	-	6	-	7.6	
3	8		III	4.6	4.8	-	4.5	-	6	
3	9		I	2.2	2.2	-	1.2	-	3.6	
4	5	Aliberta	VII	3.7	3.7	-	5.4	-	7.6	
4	8		VII	3.1	3.1	-	1.2	-	3	
4	8		VII	3.7	3.7	-	5.4	-	6.9	
4	8		VII	3.1	3.1	-	3.9	-	4.5	
4	8		VII	2.5	2.5	-	3.9	-	4.5	
5	6		VII	3.3	3.7	-	3.9	-	5.4	
5	7		IV	M	2.0	-	.8	-	4.2	
6	1		I	M	2.2	-	1.2	-	3.6	
6	1		II	2.2	2.2	-	.3	-	1.5	
6	4	Hirtella	VII	M	1.2	-	.3	-	2.8	
6	5		VII	3.5	3.7	-	3.6	-	4.2	
6	5		VII	3.1	3.1	-	3.9	-	4.5	
6	6		VII	2.5	2.5	-	5.4	-	6.6	
6	6		VII	2.5	2.5	-	2.5	-	3.6	
6	6		IV	M	2.2	-	1.5	-	3.9	
7	3		VII	M	1.2	-	4.2	-	6	
7	5		VII	4.1	5	-	4.5	-	6	
7	5		VII	2.5	2.5	-	1.2	-	4.2	
7	5		VII	3.8	4.4	-	4.5	-	5.1	
7	6		I	3.0	3.4	-	1.8	-	4.2	
8	0	Pit toniotis	I	M	2.0	-	1.9	-	3.9	
8	1		I	M	2.4	-	1.5	-	3.9	
8	1		VII	2.5	2.5	-	.3	-	2.8	
8	7		VII	3.5	3.7	-	4.2	-	6	
8	8									

D2 D1			D B H C M		FIRST BRANCH M		HEIGHT M		
C2 C1	SPECIES	SHAPE							REMARKS
X Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
0 2	Annona	II	*	2.4	-		-	4.2	
0 4	Anacardium	IV	17.8	19.4	-	3.9	-	14	
0 7		III	12.5	12.5	-	7	-	14	
0 8		VII	M	3.7	-	.8	-	3.6	
1 7	Anacardium	VII	3.7	3.7	-	1.2	-	3.6	
1 8		VII	M	2.5	-	.8	-	2.0	
1 8		VII	M	3.7	-	4.2	-	6	
1 9		VII	3.2	3.2	-	6	-	6.4	
2 7		III	14.4	15.9	-	1.8	-	11.5'	
2 9		VII	3.6	3.6	-	7.2	-	8.4	
3 2	Croton	IV	2.8	3.2	-	.3	-	4.5	
3 4	Posequeria	III	8.1	8.6	-	4.5	-	6.6	
3 7		VII	M	3.7	-	4.2	-	5.7	
3 7		VII	3.7	3.7	-	1.8	-	4.2	
3 7		VII	3.7	3.7	-	1.5	-	3.9	
3 8		VII	M	3.7	-	1.2	-	3.9	
3 8		VII	4.1	4.4	-	5.7	-	8.2	
3 8		VII	3.7	3.7	-	3.6	-	4.5	
5 0		I	M	2.4	-	.8	-	3.6	
5 1		I	M	2.4	-	.5	-	4.2	
5 3		III	M	2.6	-	.8	-	1.2	
5 7		I	4.6	4.6	-	1.8	-	4.5	
5 8		VII	3.5	3.7	-	4.2	-	5.4	
5 9		VII	4.3	4.4	-	5.7	-	7.6	
5 9		VII	3.3	3.7	-	4.5	-	6	
6 0		I	M	2.0	-	.8	-	3.6	
6 8	Luehea	IV	35.3	36.5	-	6.6	-	16	
6 9		VII	M	3.7	-	1.8	-	3.6	
7 2		IV	M	2.8	-		-	3.6	
7 5	Alibertia	III	*	1.8	-	3	-	4.2	
7 5	Palicouria	I	2.5	2.6	-	.5	-	3.9	
7 5			M		-		-		Missing or chopped
8 1	Pittoniotis	I	2.5	2.8	-	.3	-	4.5	
8 2	Anacardium	I	M	2.4	-	.8	-	3.6	
8 6		I	3.3	3.6	-	3.6	-	4.5	
8 7	Miconia	I	2.5	2.8	-	1.8	-	5.4	
8 7	Psychotria	IV	*	1.6	-	3	-	3.6	
9 0		I	2.5	3.4	-	2.8	-	3.9	
9 1		III	M	1.8	-	.3	-	3.9	
9 3		IV	2.8	3.4	-	3	-	6	

C7 C6 B7 B6 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	 1 Jan 1967	HEIGHT M 4 Jun 1967	 1 Jan 1967	REMARKS
0	4	Miconia	I	3.5	23.2	-	1.5	-	20	
1	5	Costus	III	4.2	4.2	-	2.5	-	3.6	
1	6	Costus	III	4.0	4.0	-	2.5	-	3.3	
2	2	Hirtella	I	3.3	4.5	-	1.5	-	3	
2	6									Dead or Chopped
3	2		III	M	2.7	-	3.3	-	4.2	
3	4	Posequeria								Chopped Dead
4	3		I	4.2	4.2	-	.8	-	3.3	
4	7	Belotia	III							Dead
5	7	Trema	III							Dead
5	8	Belotia	III	5.5	8.6	-	6.5	-	10.5	
5	8	Croton	III	2.7	2.7	-	3.9	-	4.8	
5	8		III	2.8	2.8	-	2.8	-	4.5	
5	9	Belotia	III	2.5	3.2	-	8.5	-	11.5	
6	2	Bursera	III	12.9	14.3	-	6	-	8	
6	2	Bursera	III	12.5	12.5	-	6	-	10	
7	8		III	M	6.2	-	9	-	10	
7	9	Belotia	III	4.8	9	-	7	-	13	
8	5	Costus	III	2.4	2.4	-	1.2	-	1.9	
8	5	Costus	III	M	2.0	-	2.8	-	3.3	
8	5	Costus	III	M	2.0	-	3	-	3.6	
8	6		III	2.5	2.5	-	1.2	-	3.6	
9	9	Annona	II	3.0	3.4	-	.2	-	5.1	

C6 C5 / B6 B5 / X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	6	Nectandra	II	3.0	3.1	-		-	3.6	
0	9		I	M	5.8	-	3	-	5.4	
3	3	Posequeria	II	2.5	3	-		-	2.8	
3	7	Rubiaceae	I	17.5	19	-	4.5	-	13.5	
5	1	Inga	I	4.1	4.2	-	1.2	-	2.8	
6	9		III	M	12.4	-	7	-	12.5	

C5 C4 B5 B4 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS
1	1		I		25.4	-	6.4	-	15.5	
1	1		III	3.8	4.4	-	2.5	-	5.1	
2	5		I	M	3.0	-	1.2	-	2.3	
3	9	Luehea	I	11.0	17.1	-	2.8	-	7.6	
4	1	Randia	I	2.8	3.0	-	.8	-	4.2	
4	1	Hirtella	II	2.5	3.0	-	.2	-	5.1	
5	2	Alibertia	I	*	1.8	-	.7	-	3.3	
6	0	Randia	I	2.8	3.0	-	2.0	-	4.5	
7	7	Posequeria	II	2.5	3.4	-	.3	-	5.1	
8	4		VII	2.8	[illegible]1	-	.7	-	2.8	
8	4		VII							Dead
9	6		III	M	2.4	-	2.0	-	3.6	

C4 C3			D B H C M		FIRST BRANCH M		HEIGHT M		
B4 B3	SPECIES	SHAPE							REMARKS
X Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
0 3		I	2.5	2.6	-	1.9	-	3.6	
0 5		III	M	2.1	-	2.0	-	2.8	
1 4	Anacardium	I	8.3	8.5	-	3.3	-	6.6	
2 3	Inga	I	22.0	22.0	-	6	-	22	
3 0		III	M	2.7	-	1.8	-	2.8	
3 6	Lafoensia	I	5.1	5.2	-	2.5	-	7.6	
3 7	Rubiaceae	I	3.3	3.4	-	.7	-	4.2	
4 3		II	M	2.8	-	.7	-	2.5	
6 2	Anacardium	I	6.3	6.8	-	2.8	-	5.4	
6 9	Anacardium	I	M	12.7	-	3	-	12.5	
7 8	Luehea	I	67.3	68.3	-	14	-	28	
8 5	Palicourea	III	2.5	3.0	-	2.5	-	5.4	

C3 C2			D B H C M		FIRST BRANCH M		HEIGHT M		
B3 B2	SPECIES	SHAPE	1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	REMARKS
X Y									
0 6			2.5		-		-		Missing
2 4		II	M	2.8	-	.8	-	4.2	
2 6		V	M	3	-	2.8	-	5.4	
2 8	Xylopia	III	18.0	18.5	-	14	-	18.5	
3 6		VII	3.0	3.1	-	3.9	-	5.4	
3 7		VII	3.3	4.4	-	3.3	-	[illegible].5	
4 2		VII	3.3	[illegible].7	-	3.6	-	4.2	
4 3		VII	4.1	4.4	-	3.6	-	4.8	
4 5		VII	2.5	2.5	-	4.5	-	3.6	
4 3		VII	2.5	2.5	-	1.5	-	3.6	
4 4		VII	3.7	3.7	-	3.9	-	4.8	
4 4		VII	4.1	4.4	-	1.5	-	3.6	
4 5		III							Dead or dying
4 6		VII	3.1	3.1	-	4.2	-	6	
4 7		VII							Dead or dying
4 7		VII	3.7	3.7	-	4.2	-	5.4	
4 7		VII	2.5	2.5	-	1.2	-	3	
4 8		VII	M	2.5	-	1.2	-	3.3	
5 1		I	2.5	3.0	-	3.3	-	5.4	
5 3		VII	3.7	3.7	-	3.9	-	5.7	
5 8		VII	3.7	3.7	-	4.2	-	6	
5 4		VII	3	3.1	-	4.5	-	4.8	
5 5		VII	3.5	3.7	-	4.5	-	5.4	
5 7		VII	3.0	3.1	-	4.2	-	4.8	
5 7		VII	2.8	3.1	-	1.8	-	4.5	
6 4		VII	2.8	3.7	-	2.8	-	3.6	
6 4		VII	2.8	3.1	-	4.5	-	5.1	
6 4		VII							Dying
6 5		VII	3.1	3.1	-	4.2	-	6	
6 6	Luehea	I	10.3	10.3	-	6	-	24	
6 6		VII	3.1	3.1	-	3.9	-	4.5	
6 6		VII	3.3	3.7	-	4.5	-	6	
6 6		VII	M	3.7	-	3.6	-	4.2	
6 6		VII	M	3.1	-	3.6	-	4.5	
6 7		VII	M	3.7	-	3.3	-	4.2	
6 7		VII	2.5	2.5	-	.8	-	3	
7 3	Anacardium	I	61.0	61.0	-	12	-	34	
9 6		II	M	3.6	-		-	2.5	

C2 C1 B2 B1 X	 Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	 1 Jan 1967	HEIGHT M 4 Jun 1967	 1 Jan 1967	REMARKS
0	1	Luehea	I	*	22.0	-		-	5.4	
0	1									Dead or broken
0	1		I	M	2.4	-	1.2	-	3.6	
0	7	Rourea		3.8		-		-		Missing
1	3	Spondias	I	39.2	39.2	-	10.5	-	25	
1	5	Talisia	III	4.1	4.8	-	4.8	-	6	
1	9	Vine		*						
4	0	Anacardium	I	23	23	-	6.9	-	15	
4	0		II	M	2.2	-	.5	-	2.8	
3	8			2.4	2.4	-	.8	-	2.5	
4	3		III	4.8	5.2	-	4.2	-	6	
4	4	Lacistema	I	2.8	3.4	-	2.0	-	4.2	
5	6		VII	3.5	3.7	-	2.8	-	4.2	
5	6		VII	3.5		-	.8	-	1.8	
6	0	Miconia	IV	2.5		-	.5	-	3.3	
7	3		II	M	2.4	-	1.8	-	3.6	
7	3		II	M	2.4	-	1.5	-	3.6	
7	1	Lafoensia	I	2.8	3.4	-	1.2	-	3.6	
7	8		I	2.6	2.6	-	1.6	-	3.6	
7	9		I	M		-	.5	-	4.5	
7	9		I	M	2.8	-	.8	-	5.1	
8	2	Flacourtiaceae	I	3.5	4.8	-	1.5	-	4.5	
8	5									Chopped
8	6		VII	2.8	5.6	-	1.8	-	3.9	
8	7		VII	4.3	5	-	1.8	-	5.1	

B7 B6 / A7 A6 / X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	D B H C M 1 Jan 1967	FIRST BRANCH M 4 Jun 1967	FIRST BRANCH M 1 Jan 1967	HEIGHT M 4 Jun 1967	HEIGHT M 1 Jan 1967	REMARKS
0	1			M						Missing
0	8			M	3.2	-	3	-	4.5	
0	8			4.1	4.2	-	2.8	-	4.2	
0	8			4	4	-	2.5	-	4.8	
0	8			M	4	-	2.8	-	5.1	
0	8			M	4.2	-	1.8	-	4.5	
0	9	Cecropia	III	16.8	17.5	-	8	-	19	
1	8		V	3.0	4	-	3	-	5.1	
1	3	Croton	II	3.5	4.2	-		-	3.3	
1	8			M	4	-	3	-	5.1	
1	8		V	3.0	4.4	-	.8	-	4.8	
2	7	Croton	I							Dead
3	1	Inga	III	1.	4	-	3.9	-	5.1	
3	9	Piper	I	2.5	2.7	-	.8	-	3.3	
5	1		VII	2.7	2.7	-	5.4	-	6.9	
5	1		VII	3.1	3.1	-	3.6	-	5.7	
5	2			2.8	3.4	-	3	-	4.5	
5	2		VII							Dead
5	7	Anacardium	I	23.2	25	-	2.7	-	18	
6	1		VII	3.7	3.7	-	3.9	-	6	
6	1		VII	2.8	3.4	-	.8	-	2.8	
6	2		VII	2.5	3.7	-	3.6	-	5.4	
6	2		VII	2.7	2.7	-	4.8	-	5.4	
6	2		VII	3.7	3.7	-	3	-	4.8	
6	3	Copaifera	III	4.6	5.0	-	3.3	-	3.9	

B6 B5 A6 A5 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	2	Andira	I	10.3	10.5	-	2.8	-	6.9	
0	5		I	M	3.4	-	1	-	2.5	
0	9	Annona	I	25	25	-	5.7	-	16	
1	2		IV	M	1.8	-		-	3.3	
2	1									Dead
2	4		VII	3.7	3.7	-	2.0	-	3	
2	8		I	21	21	-	48	-	14.5	
3	3		VII	3.3	3.7	-	3	-	4.2	
3	3		VII	3.4	3.4	-	3.6	-	4.5	
3	4		VII	3.4	3.4	-	3.6	-	5.1	
3	5		VII	3.7	3.7	-	3	-	4.2	
3	5		VII	3.1	3.1	-	1	-	2.9	
3	5		VII	2.7	2.7	-	1.8	-	3	
3	7	Lafoensia	III	7.1	8.2	-	3.6	-	5.4	
4	4		VII	3.0	3.7	-	2.5	-	3.9	
4	4		VII	3.1	3.1	-	3	-	5.4	
4	4		VII	2.5	2.5	-	2.5	-	3.9	
4	8	Posequeria	I	3.0	3.0	-	1.2	-	3.9	
6	4		I	2.8	3	-	1.8	-	3.3	
6	5		I	3.0	3	-	.8	-	2.8	
8	9	Anacardium	I	4.8	5.1	-	.8	-	4.5	
9	2	Croton	I	1.8	1.8	-	.8	-	2.8	
9	8									Does not exist

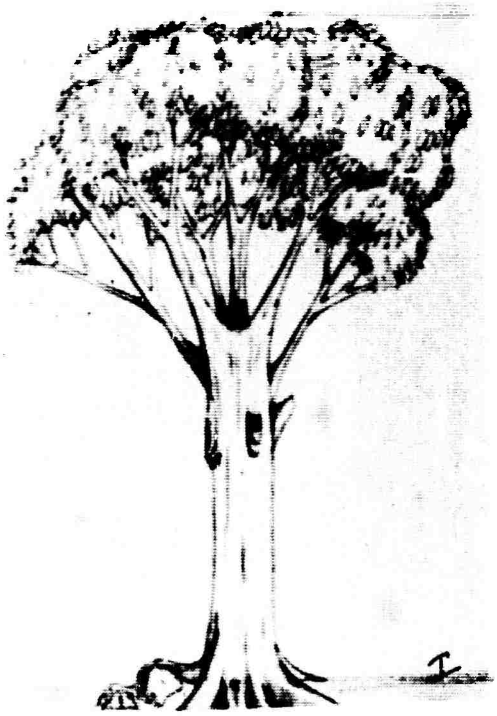
B5 B4 / A5 A4 / X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	4		I	M	2.7	-	.8	-	3.3	
0	4									Dead
0	8		I	M	2.4	-	1.2	-	4.5	
0	8		I	M	9.2	-	.8	-	6.6	
1	0		V	3.5	4.5	-	3	-	5.4	
1	1		V	3.1	3 1	-	1.8	-	3.6	
1	2		I	M	3.1	-	1.5	-	3	
1	2		IV	M	2.1	-	.3	-	2.5	
1	3		IV	M	3.0	-	.5	-	1.8	
2	0		V	4.1	4.2	-	2.0	-	5.4	
2	0		V	4.1	4.2	-	3	-	5.1	
2	1		V	3.2	3.2	-	1.9	-	4.5	
2	1		I	3.4	3.4	-	3.3	-	6	
2	6		IV	4	2.2	-	.3	-	3.3	
3	4	Lafoensia	III	10.1	10.5	-	10	-	12	
4	9		II	M	4.0	-	1.5	-	1.7	
8	1		I	M	2.5	-	.5	-	2.8	
6	8	Spondias	I	33.3	33.3	-	12	-	24.5	
9	5	Flacourtiaceae	III	4.6	4.8	-	4.8	-	5.4	

B4 B3 A4 A3 X	Y	SPECIES	SHAPE	D B H C M 1 Jun 1966	1 Jan 1967	FIRST BRANCH M 4 Jun 1967	1 Jan 1967	HEIGHT M 4 Jun 1967	1 Jan 1967	REMARKS
0	7	Luehea	I	26.8	26.8	-	6	-	13.5	
1	4	Annona	III	2.5	4.9	-	4.5	-	6	
1	9		III	9.6	9.9	-	6	-	8.4	
2	3		I	M	3.4	-	1.5	-	3.9	
2	6	Luehea	I	71.0	74.3	-	12	-	26	
2	6		III	M	2.8	-	3	-	4.8	
4	6	Anacardium	I	4.6	5.2	-	2.8	-	4.8	
9	2	Anacardium	I	41.9	45.8	-	3.3	-	28	

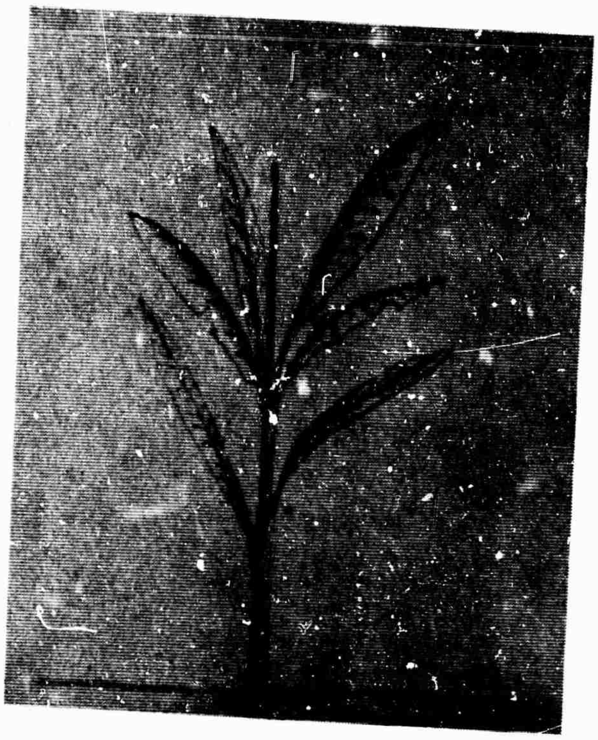
B3 B2			D B H C M		FIRST BRANCH M		HEIGHT M		
A3 A2		SPECIES	SHAPE						REMARKS
X	Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
2	4	Miconia or Luehea	I	M	2.2	-	6	-	9	
3	8		I							Dead
5	4		VII	5	5	-	3.3	-	4.5	
5	4		VII	3.5	4.4	-	1.2	-	3.6	
5	5		VII	3.1	3.1	-	3.9	-	4.5	
6	1	Spondias	I	26.1	32.5	-	9.5	-	22	
6	1	Spondias	I	29.9	35.1	-	9.5	-	22	
6	4		VII	3.5	3.7	-	.8	-	3.3	
6	4		VII	3.7	3.7	-	1.5	-	3.9	
8	0		I	5.1	7.8	-	3.9	-	6.6	
8	6	Hirtèlla	II	2.5	3	-	.3	-	4.5	

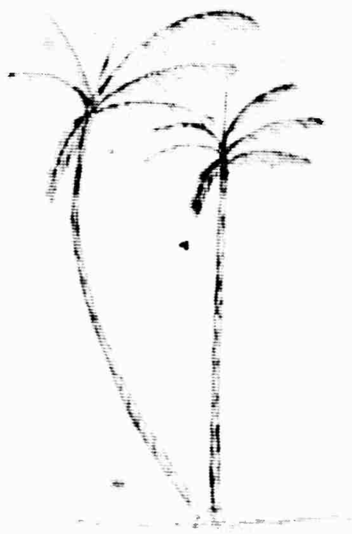
B2 B1			D B H C M		FIRST BRANCH M		HEIGHT M		
A2 A1	SPECIES	SHAPE							REMARKS
X Y			1 Jun 1966	1 Jan 1967	4 Jun 1967	1 Jan 1967	4 Jun 1967	1 Jan 1967	
0 0	Andira	I	4.3	4.6	-	2.5	-	4.2	
3 6									Dead
5 2	Piper	II	3.2	3.2	-	.8	-	3.9	
5 2		III	2.2	2.2	-	1.8	-	3.3	
5 4	Annona	III	2.3	2.6	-	3.3	-	3.9	
5 8	Luehea	I	125.	125.	-	14	-	28.5	
7 3	Copaifera	I	2.5	3	-	3	-	3.9	
7 4		I	*	3	-	.8	-	3.6	
8 5	"Quipo" Cavanillesia	III	M	3.0	-	3.6	-	4.2	
8 7		I	M	2.4	-	1.5	-	3	
9 6		I	2.8	2.8	-	1.8	-	3.6	
9 7		I	M	4	-	1.5	-	3.9	

DRAWINGS REPRESENTING SHAPES OF TREES IN ALBROOK FOREST.



DRAWINGS REPRESENTING SHAPES OF TREES IN ALBROOK FOREST.





- APPENDIX D -

DAILY OCCURRENCE OF COEFFICIENT OF HAZE

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Time of Occurrence of Minimum, Maximum, and Daily Means of the Coefficient of Haze (COH) Units per 1000 Linear Feet at Chiva Chiva

Note: "Hour" refers to start of one-hour periods during which the indicated value was obtained

Date	Minimum	Hour	Maximum	Hour	Mean
1966					
Apr.					
1	0.637	1615	2.688	2115	1.259
2	0.708	1915	1.698	0515	1.270
4	0.208	2100	1.610	1400	0.518
5	0.134	1800	0.774	1400	0.370
6	0.128	0200	0.642	0000	0.313
11	0.170	0900	1.768	1700	0.666
12	0.283	0800	1.270	1600	0.654
13	0.255	0300	3.260	1600	0.817
14	0.142	0900	1.270	0600	0.488
15	0.156	1021	0.920	1321	0.401
18	0.212	1925	0.534	1525	0.357
19	0.212	0525	0.424	0625	0.339
20	0.254	1720	0.707	1120	0.455
21	0.255	2345	0.920	1345	0.496
22	0.184	0845	0.538	0645	0.341
23	0.054	1705	0.357	1305	0.151
24	0.018	1105	0.178	1705	0.087
25	0.036	0500	0.071	0700	0.056
28	0.022	2035	0.536	1235	0.169
29	0.128	0035	0.228	0135	0.146
May					
3	0.032	2215	0.139	1215	0.083
4	0.086	0015	0.500	0415	0.241
5	0.018	1150	0.139	1950	0.073
6	0.071	0350	0.182	1255	0.106
7	0.050	1055	0.171	1255	0.096
8	0.028	1055	0.136	0255	0.076
9	0.007	1045	0.107	0855	0.066
10	0.054	1445	0.203	1645	0.133
11	0.107	0045	0.350	0445	0.210
12	0.032	1500	0.214	1100	0.073
13	0.0	0300	0.071	1700	0.035
14	0.0	0100	0.071	0300	0.041
15	0.007	0700	0.064	2300	0.042
16	0.018	2300	0.089	0300	0.052
17	0.028	0100	0.132	0700	0.094

Date	Minimum	Hour	Maximum	Hour	Mean
May					
19	0.054	1250	0.178	1850	0.120
20	0.018	0650	0.118	0050	0.060
21	0.0	0900	0.064	0100	0.028
22	0.0	1500	0.107	0100	0.046
23	0.0	1700	0.125	1900	0.057
24	0.086	0100	0.216	1300	0.139
25	0.054	1245	0.286	0000	0.127
26	0.036	0445	0.114	2045	0.071
27	0.075	0645	0.125	1700	0.100
28	0.050	0700	0.128	0100	0.074
29	0.028	0500	0.125	2300	0.058
30	0.036	2100	0.171	1300	0.120
31	0.028	1645	0.221	0100	0.088
Jun.					
1	0.004	1640	0.157	0845	0.073
2	0.032	0040	0.214	0840	0.086
3	0.028	0240	0.182	2040	0.101
4	0.032	0840	0.064	1840	0.044
5	0.018	1040	0.128	1640	0.051
6	0.0	0040	0.175	1555	0.049
7	0.004	0155	0.143	2300	0.063
8	0.0	0500	0.164	1100	0.069
9	0.039	1648	0.114	0635	0.053
23	0.021	1600	0.086	[illegible]	0.059
24	0.0	0200	0.064	0800	0.029
25	0.004	0700	0.094	0300	0.046
26	0.0	0300	0.077	1700	0.028
27	0.0	1800	0.167	2400	0.068
28	0.043	0200	0.214	2000	0.128
29	0.0	1700	0.257	0200	0.094
30	0.004	0300	0.205	1350	0.093
Jul.					
1	0.0	0750	0.120	0550	0.042
2	0.0	1200	0.077	1000	0.024
3	0.0	0200	0.103	1200	0.028
4	0.0	1000	0.056	1200	0.020
5	0.0	1200	0.086	1615	0.037
6	0.0	0015	0.077	0815	0.024
7	0.0	0400	0.026	0200	0.005
13	0.032	1940	0.072	2340	0.053
14	0.0	0940	0.072	1540	0.026
15	0.0	0400	0.040	0800	0.020
19	0.0	2135	0.108	1535	0.059

Date	Minimum	Hour	Maximum	Hour	Mean
Jul.					
20	0.0	0635	0.056	0135	0.030
21	0.063	2043	0.065	2243	0.064
22	0.035	1243	0.112	1800	0.078
23	0.019	0800	0.068	0200	0.055
25	0.040	1550	0.068	1950	0.055
26	0.016	1350	0.072	1150	0.046
27	0.023	1940	0.088	1740	0.056
28	0.014	0540	0.121	1940	0.086
29	0.0	1550	0.093	1340	0.048
30	0.0	1950	0.072	0350	0.045
31	0.009	0150	0.088	1550	0.049
Aug.					
1	0.0	2150	0.074	0150	0.033
2	0.004	1350	0.063	1150	0.034
3	0.014	0310	0.140	1420	0.050
4	0.0	0425	0.091	1225	0.033
5	0.051	0835	0.280	1235	0.098
6	0.014	0900	0.112	1300	0.045
7	0.040	1100	0.126	1900	0.079
8	0.021	1545	0.096	0100	0.060
9	0.005	2137	0.112	0145	0.043
10	0.016	1337	0.121	1137	0.060
11	0.002	1615	0.058	2215	0.030
12	0.016	1015	0.133	1215	0.042
13	0.0	1515	0.086	0315	0.030
14	0.019	0115	0.133	2315	0.044
15	0.021	2350	0.123	1115	0.067
16	0.005	1530	0.112	1150	0.036
17	0.0	0930	0.091	1735	0.029
18	0.0	0935	0.098	1335	0.048
19	0.002	1730	0.102	2330	0.057
20	0.0	1930	0.107	1730	0.057
21	0.0	0130	0.096	1930	0.052
22	0.0	1530	0.070	0530	0.043
23	0.0	0330	0.107	1130	0.048
24	0.0	1130	0.077	0130	0.038
25	0.002	1015	0.186	1618	0.052
26	0.026	0418	0.121	0618	0.075
27	0.016	1700	0.058	2300	0.038
28	0.006	[illegible]100	0.097	1300	0.035
29	0.010	1740	0.085	2140	0.050
30	0.004	0140	0.116	1405	0.047
31	0.0	0805	0.107	1620	0.040

Date	Minimum	Hour	Maximum	Hour	Mean
Sep.					
1	0.017	0020	0.107	1020	0.071
2	0.019	1812	0.116	1218	0.056
3	0.0	0800	0.078	0200	0.034
4	0.0	0400	0.078	2200	0.036
5	0.019	1630	0.107	2030	0.057
6	0.025	0430	0.097	0030	0.063
7	0.025	2035	0.175	0807	0.070
8	0.0	0035	0.068	0235	0.029
9	0.016	0630	0.146	1430	0.063
10	0.010	1835	0.107	0235	0.056
11	0.016	1635	0.097	1235	0.042
12	0.027	0435	0.064	1500	0.042
13	0.019	0900	0.116	1944	0.064
14	0.027	1344	0.146	2137	0.068
15	0.043	2337	0.194	0137	0.087
16	0.010	2155	0.142	1555	0.064
17	0.006	1755	0.077	0155	0.039
18	0.0	0755	0.057	0355	0.024
19	0.020	0155	0.193	1130	0.056
20	0.030	1330	0.118	0730	0.075
21	0.0	1815	0.142	0415	0.076
22	0.045	0815	0.071	0015	0.059
23	0.017	1945	0.172	2345	0.079
24	0.029	1545	0.105	0345	0.072
25	0.027	1545	0.153	1145	0.063
26	0.0	1145	0.096	1545	0.048
27	0.0	0945	0.038	0345	0.024
28	0.084	2110	0.213	1710	0.123
29	0.020	0010	0.123	2110	0.072
30	0.044	1910	0.148	1755	0.086
Oct.					
1	0.033	0755	0.123	1800	0.060
2	0.0	0400	0.190	2200	0.066
3	0.008	1000	0.107	2230	0.059
4	0.008	0230	0.090	0030	0.056
5	0.031	0300	0.056	0500	0.041
6	0.016	1000	0.082	0700	0.052
7	0.038	1130	0.072	1920	0.052
8	0.036	0520	0.067	0320	0.044
9	0.0	1720	0.052	0320	0.024
10	0.025	1830	0.167	1630	0.058
11	0.0	1030	0.085	2155	0.052
12	0.028	0555	0.156	1555	0.072
13	0.045	0955	0.483	1555	0.139

Date	Minimum	Hour	Maximum	Hour	Mean
Oct.					
14	0.0	1535	0.156	0155	0.065
15	0.011	1335	0.078	0735	0.047
16	0.011	2135	0.106	0335	0.051
17	0.026	0535	0.081	2335	0.052
18	0.061	0335	0.156	2335	0.102
19	0.026	1723	0.099	2323	0.062
20	0.021	1533	0.155	2242	0.082
21	0.021	1242	0.192	1503	0.096
22	0.007	1903	0.060	0303	0.029
23	0.014	0903	0.085	1703	0.035
24	0.014	1940	0.139	1340	0.043
25	0.0	0340	0.078	1830	0.034
26	0.0	0030	0.140	1726	0.056
27	0.018	0526	0.135	1126	0.065
28	0.026	0830	0.114	1030	0.059
29	0.0	1200	0.064	0400	0.025
30	0.006	0800	0.037	0200	0.018
31	-	-	0.057	2235	-
Nov.					
1	0.014	1435	0.142	1035	0.074
2	0.021	2240	0.170	1040	0.069
3	0.0	1240	0.057	0040	0.026
4	0.0	0633	0.031	0033	0.020
5	0.0	1345	0.036	2245	0.015
6	0.0	1545	0.043	0745	0.018
7	0.0	0945	0.135	1545	0.042
8	0.014	1835	0.074	1435	0.052
9	0.028	0235	0.037	0035	0.031
10	0.018	2335	0.213	0535	0.066
11	0.0	1230	0.057	2230	0.021
12	0.0	1230	0.057	1630	0.035
13	0.0	2230	0.043	1630	0.022
14	0.014	0230	0.036	0430	0.022
15	0.0	2335	0.128	1735	0.055
16	0.014	0535	0.121	0135	0.042
17	0.0	1620	0.043	0020	0.025
18	0.0	0420	0.045	0220	0.021
19	0.0	0924	0.040	0124	0.021
20	0.0	0924	0.038	1724	0.016
21	0.0	1324	0.033	0924	0.015
22	0.0	0724	0.064	1635	0.034
23	0.004	2035	0.114	0235	0.033
24	0.0	0035	0.045	0435	0.020
25	0.0	0235	0.028	2025	0.016

Date	Minimum - Hour		Maximum - Hour		Mean
Nov.					
26	0.0	1225	0.031	2025	0.017
27	0.0	1225	0.071	1725	0.0[illegible]
28	0.0	1425	0.057	0025	0.023
29	0.0	0715	0.068	1315	0.022
30	0.0	1514	0.041	0515	0.019
Dec.					
1	0.003	1228	0.085	2028	0.044
2	0.0	1836	0.036	0828	0.017
3	0.0	1036	0.034	0836	0.018
4	0.0	2036	0.074	0236	0.029
5	0.006	0236	0.106	0636	0.038
6	0.0	0836	0.128	1436	0.041
7	0.0	1236	0.045	0436	0.018
8	0.001	0035	0.082	1435	0.040
9	0.0	1645	0.106	0635	0.038
10	0.0	1245	0.082	0245	0.036
11	0.0	1445	0.047	2245	0.017
12	0.003	0645	0.056	1540	0.021
13	0.0	0950	0.052	0350	0.020
14	0.0	0950	0.036	2035	0.019
15	0.003	0835	0.023	0235	0.012
16	0.0	0435	0.050	0835	0.018
17	0.0	0435	0.023	0235	0.013
18	0.0	0835	0.028	0235	0.010
19	0.0	1045	0.031	2245	0.016
20	0.0	1245	0.040	0045	0.020
21	0.0	0430	0.033	1830	0.015
22	0.017	0030	0.036	1030	0.024
23	0.0	1630	0.037	0030	0.018
24	0.0	1230	0.024	0830	0.012
25	0.0	0030	0.021	2230	0.009
26	0.0	1230	0.043	1430	0.025
27	0.0	1434	0.044	0634	0.016
28	0.0	0034	0.017	2230	0.008
29	0.0	1230	0.036	1030	0.018
30	0.0	1030	0.028	0830	0.010
31	0.0	0830	0.028	0630	0.013
1967					
Jan.					
1	0.026	0430	0.057	1030	0.042
2	0.034	0030	0.085	2230	0.059
3	0.048	1635	0.081	0430	0.055
4	0.028	1435	0.071	0035	0.051

Date	Minimum - Hour		Maxium - Hour		Mean
Jan.					
5	0.011	1234	0.031	0034	0.023
6	0.0	1243	0.040	0843	0.017
7	0.0	1617	0.031	2017	0.015
8	0.006	1217	0.037	0817	0.015
9	0.0	1620	0.017	0817	0.010
10	0.0	1220	0.036	2017	0.014
11	0.0	1418	0.054	2138	0.022
12	0.0	0338	0.038	2045	0.017
13	0.0	1616	0.028	2016	0.013
14	0.0	0416	0.026	1416	0.013
15	0.004	0016	0.028	2016	0.015
16	0.0	1720	0.050	0016	0.015
17	0.0	0320	0.021	1320	0.007
18	0.0	1020	0.094	2214	0.028
19	0.068	1620	0.111	1014	0.094
20	0.043	0620	0.099	0820	0.057
21	0.014	0814	0.052	2214	0.025
22	0.014	1814	0.040	0814	0.025
23	0.0	1414	0.028	0214	0.013
24	0.0	1615	0.045	2215	0.022
25	0.010	0015	0.048	2219	0.027
26	0.007	1526	0.037	1019	0.026
27	0.023	0126	0.045	1126	0.029
31	0.0	1135	0.040	2135	0.010
Feb.					
1	0.0	1620	0.023	2220	0.013
2	0.0	1807	0.055	1607	0.032
3	0.018	1610	0.067	2210	0.039
4	0.012	1210	0.053	0010	0.028
5	0.016	1810	0.053	0210	0.033
6	0.0	1210	0.044	0810	0.017
7	0.0	1550	0.053	0826	0.022
8	0.0	1150	0.084	2200	0.033
9	0.0	1400	0.077	0200	0.038
10	0.0	1722	0.056	2322	0.028
11	0.019	1522	0.070	0722	0.037
12	0.004	2322	0.049	0122	0.029
13	0.0	1615	0.023	1322	0.018
14	0.0	1546	0.049	1415	0.020
15	0.0	2154	0.053	0346	0.027
16	0.009	1617	0.028	1354	0.019
17	0.016	1815	0.049	2215	0.029
18	0.0	1615	0.056	0615	0.029
19	0.007	1015	0.035	0815	0.021

Date	Minimum -	Hour	Maximum -	Hour	Mean
Feb.					
20	0.0	1526	0.053	2126	0.027
21	0.026	0126	0.074	2214	0.038
22	0.0	1414	0.067	1814	0.039
23	0.0	0614	0.049	0814	0.030
24	0.018	1316	0.055	0116	0.035
25	0.007	1557	0.049	0757	0.025
26	0.005	0557	0.123	2157	0.055
27	0.014	1633	0.132	1357	0.072
28	0.018	0433	0.067	2116	0.037

UNCLASSIFIED
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13. ABSTRACT

This report, the third in a series of semiannual progress reports of the Environmental Data Base Project, presents a resume of Project objectives and methods and descriptions of the operational sites.

The Climate section (Part IV) shows the data collected and instrumentation used with a description of automatic instrumentation planned. Analyses of daily temperature variations and a discussion of soil-surface temperature determination are presented.

The Soils and Hydrology section (Part V) presents analyses of soil-moisture profiles and soil-strength profiles and their interrelationships. Detailed information on soil profiles and physical characteristics is presented in an appendix.

The Vegetation section (Part VI) presents analyses of forest litter accumulation. Information on seedling characteristics and seed germination, and a revised vegetation inventory and plot for the Albrook Forest site are given in appendices.

The section dealing with Microbiology and Chemistry of the Atmosphere contains papers on: (a) airborne and surface deposited microorganisms; (b) observations of microbial populations of the forest soil; and (c) a discussion of atmospheric particulate matter.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Humid Tropics						
Tropic Environment						
Climate						
Microclimatology						
Micrometeorology						
Soil Trafficability						
Tropic vegetation						
Microbiology						
Atmospheric contaminants						
Data Base						